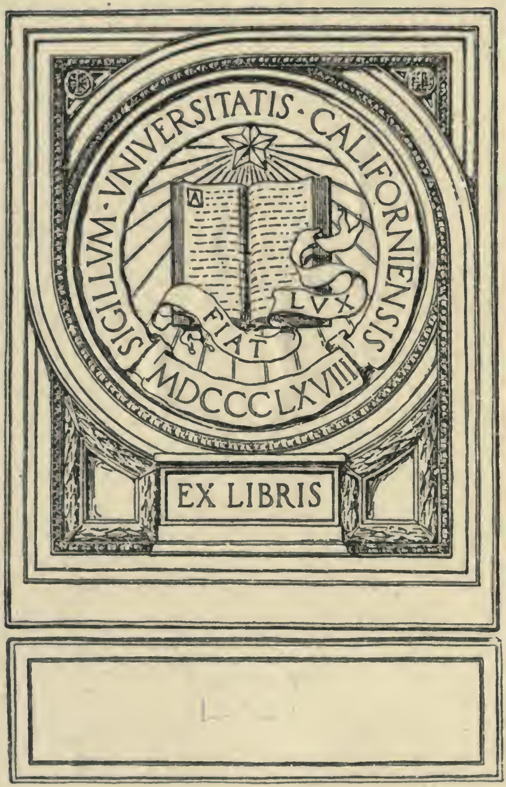
PRINCIPLES·AND·PRACTICE
OF
SCHOOL·GARDENING

ALEXANDER·LOGAN



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THE PRINCIPLES AND PRACTICE OF SCHOOL GARDENING

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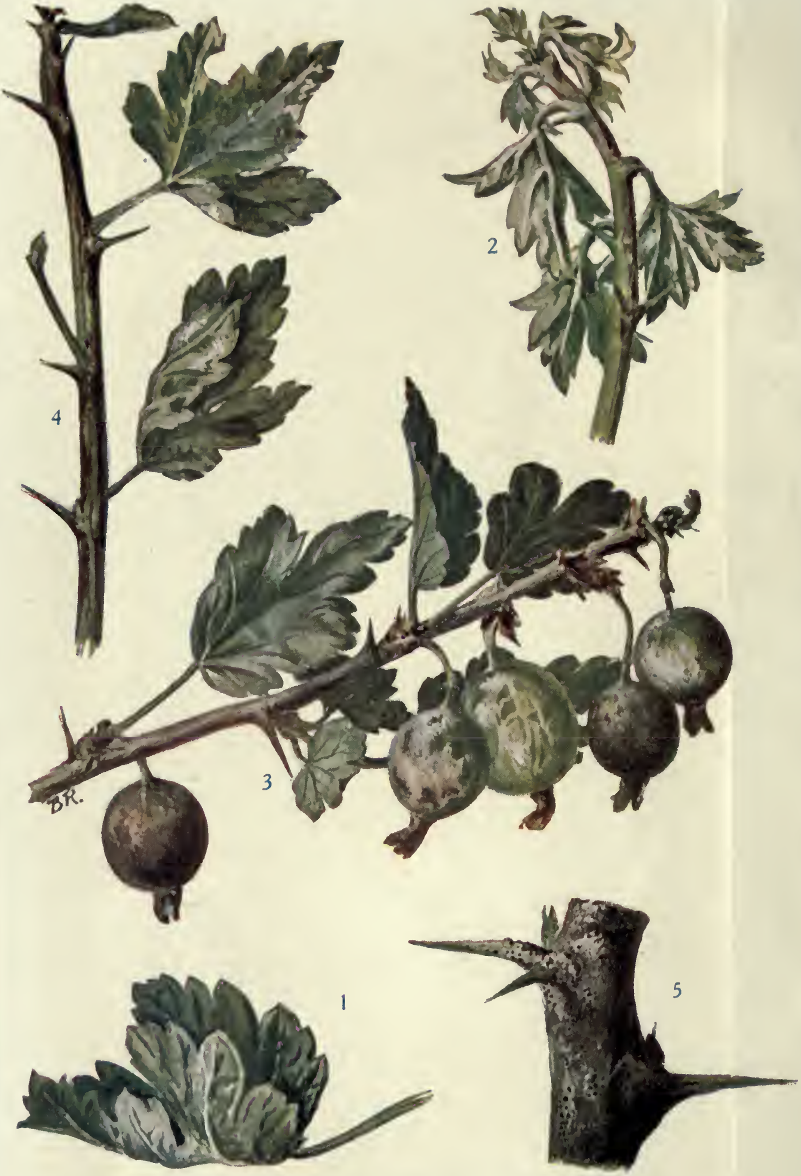

AMERICAN GOOSEBERRY MILDEW

1. Early or "summer" stage on leaf (nat. size); 2. Early or "summer" stage on young shoot (nat. size); 3. Diseased berries on previous year's shoot with unaffected leaves (nat. size); 4. Affected leaves and shoot, showing "chocolate" or second stage on the latter (nat. size); 5. Grey or "winter" stage, showing winter fruits or perithecia as black dots (enlarged).

PRINCIPLES AND PRACTICE
OF
SCHOOL GARDENING

BY

ALEXANDER LOGAN

HEAD OF SUPPLEMENTARY DEPARTMENT, GORDON SCHOOLS, HUNTLY
AUTHOR OF "THE SCHOOL GARDEN"

WITH 102 *ILLUSTRATIONS AND COLOURED FRONTISPIECE*

UNIV. OF
CALIFORNIA

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PREFACE

This volume represents an attempt to meet the present need for a text-book on School Gardening which shall deal primarily not with "gardening" *per se* but with the educative aspect of the subject, and, in virtue of the fact that the method of presentation adopted is mainly experimental and practical, shall be in accordance with the scientific educational practice of the age.

The method prescribed is that which has been found suitable in dealing with pupils between twelve and sixteen years of age; the matter included is that which, after five years of experience as a teacher of the subject, the author considers to be most usable from an educational point of view and most essential from the standpoint of horticulture and rural science. The choice of the matter has been decided by a process of elimination. In each of four successive years the study of the soil, of the growing plant, of manurial conditions, and of fruit-trees and bushes respectively, was taken up with pupils of the above-mentioned age; those features which proved most adaptable to the educational requirements of these pupils are incorporated in this volume, and those which, in the author's opinion, were of lesser educative value have been omitted.

The horticulturist may demur to the omission of certain details; individual teachers may perhaps find certain aspects unsuited to their tastes or requirements. The author for his part merely seeks to present a detailed syllabus of garden work which experience has taught him is valuable educationally; and the volume is written in the hope that teachers and pupils who are engaged in this form of school work may find in it a sane and serviceable guide.

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INTRODUCTION

School gardening is a form, or better perhaps, a modification and development of Nature Study—a subject the educative value of which has been so often discussed and is so universally accepted, that remark upon it here is almost unnecessary. From the lowest to the highest class of the elementary school, this subject of study is to-day one of the most useful at the disposal of the teacher. But if the method usually adopted with pupils in the study of Nature be analysed, it will be found to be almost wholly observational, while the study itself arrives at little save the acquisition of information and the habit of acquiring it by observation. This criticism is not intended to be in any way adverse; for as an educative factor in the development of a child up to the age of twelve such study is undoubtedly of great potentiality. The child is now at the stage of more or less "spontaneous" attention, when the mind leaps from detail to detail with no further end in view than the accumulation of information for its own sake.

But about the age of twelve or thirteen there comes a change in the mental attitude of the pupil. Reflection begins to dawn. He is entering upon the stage of "reflective" attention. As a result, the acquisition of information for its own sake begins to lose interest for him, mere information as such begins to be of use only as it aids him in solving some problem, aids him in thinking, in arriving at a conclusion. Thus the ordinary methods of Nature Study, the essence of which is observation, no longer satisfy the requirements of the pupil, and the teacher dare not disregard this change in the mental and intellectual attitude of the boy if his teaching is to be effective. He must, therefore, suit this subject of school work to the stage of advancement of the pupil.

The study of Nature, then, which is suited to the requirements of a boy of thirteen should at this stage begin to have an issue beyond mere observational work; observation must no longer be an end in itself; it must be but a step in the processes of a larger whole; must have an influence upon the activities of the pupil; must be thought-compelling with a view to action, mental or physical, or both.

It need scarcely be remarked that horticulture or gardening as such cannot be said to meet these requirements. A pupil may pass through an elaborate course of gardening having an end purely horticultural, and emerge with little save an accumulation of information and a knowledge of routine. So long as outward results in the form of crops and a knowledge of horticultural facts are the primary end in view, rather than the mental activities necessitated by a study of the fundamental principles underlying operations, and the intellectual growth of the pupil as he reflects and plans and decides in order to bring about desired results, the educational aspects of the subject are being wholly ignored.

Prize cabbages and potatoes may be grown by either method. In one case these are the sole aim in view, and failure to produce them indicates failure of the garden work. In the other case, the aim is purely educational; growth, not vegetable but intellectual, is the main object, and failure to stimulate the latter is in no wise whatsoever compensated by growth of cabbages which would catch a judge's eye on a show table. The main end of one is the production of tangible results; of the other, by the very nature of its aim, intangible results. One method is educationally dead; the other is educationally intensely alive. One is horticulture; the other is school gardening.

In an educational course of school gardening, each operation should be viewed as a problem—a problem which confronts the pupil, which is intimately related to his gardening activities, which consequently belongs to him, is his own. To the solution of this problem, therefore, the pupil is self-impelled. He observes phenomena; selects materials which are relevant, rejects those which are irrelevant; notes the relations existing between the facts selected; judges what their resultant effects will be in operation; and decides upon the course of action to be adopted.

To ensure that the student experiences each of these mental conditions in turn, the observational, experimental, and practical part of each operation must be dealt with first. Thus the student should be encouraged to arrive at his own conclusions as a result of his own observations; and consequently the observations are his own, the mental activity occasioned by the problem is his own, the intellectual gain is wholly his own. In case, however, his observations may be incomplete and as a result his conclusions be wrong, or, being based on insufficient data, be not wholly justifiable, the teacher or the text-book should also present the matter in the light of previously-taken observations in order that a correct solution of the problem may be arrived at. By this method of dealing with the subject the student is encouraged to consider the experience and conclusions of others upon the subjects of his experiments.[1]

A course of work in School Gardening implies the necessity of part of the garden-ground being laid out as an experimental plot. Indeed, one is inclined to venture the opinion that such a plot is absolutely necessary if school gardening is to rise above the level of mere horticulture. In this plot is carried out the most educative part of garden work. Here the student may observe plant-growth under any conditions he may devise. He is instructed here to place the plant in unfavourable circumstances, so that he may examine and learn from the result upon the crop; to improve the conditions, in order to find out whether the plant responds; to teaching is to be effective. He must, therefore, suit this subject of school work to the stage of advancement of the pupil.

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To arrive at this result with intelligence, more than the conditions under which the plant is placed should be considered. The very nature and structure of the plant itself must come under examination, so that the student may judge how best he may vary his treatment according to the needs of different crops, and that at different stages in the growth of each. Accordingly he maltreats many of the inhabitants of this plot; he cuts away buds, imprisons a leaf, breaks off a branch, even takes away a whole stem, or tears up a plant by its roots—all for the purpose of acquiring useful knowledge by observation and reasoning.

These operations he cannot perform in his ordinary plot; this must be well-kept and tidy, and is intended to demonstrate the results of the knowledge he has acquired by observation and deduction in the experimental plot; the crops here are meant for harvesting, not for the often harsh treatment of experimentation. In the ordinary plot he does what good sense leads him to do. In the experimental plot he sees in operation the laws which govern his actions in the ordinary plot; he comes to realise that what is known as common sense in this instance is but the right application of useful, usable knowledge of certain of the laws of nature. Thus, it is hoped, may be developed not the mechanical skill which is the result of routine, but the intelligent skill which grows out of scientific method.

Present-day demands involve the making of permanent paths bordered by more or less permanent edgings; in other words, they require that the garden should be laid out once and for all at the very outset. This plan is, however, contrary to educational principles. In the autumn of each year the whole garden-ground, with the exception perhaps of the fruit plot, the rose plot, and the herbaceous border, should be dug over; all boundaries between plots, all walks, etc., should be obliterated, and the whole ground measured and laid out afresh by a new set of students in early winter or in the following spring.

The garden will in all probability suffer somewhat from the point of view of spectacular effect if this method be adopted; the educational benefits, however, will more than counterbalance such paltry loss. At present this advice is heretical; but should even a few teachers become convinced of the gain which must accompany such yearly laying-out of the ground, and acting in accordance with their convictions decide upon having unmade earth paths without permanent edgings, others will follow suit, and much will be accomplished towards the placing of school gardening upon a sound educational basis and the freeing of it from the reproach of being mere horticulture.

This question of yearly laying-out may seem to some a matter of small educational importance, but in reality it is fundamental, and may be indicative of the primary end in view in the whole work of the school garden, namely, the intellectual development of the pupils, and not the cultivation of prize crops. And after all, little inconvenience will be experienced as a result of having earth paths. The soil may easily be consolidated, and, in any case, outdoor work must give place to indoor experimental work in connection with the garden during wet muddy weather.

As the subjects of school gardening and woodwork are complementary in the education of a boy between the ages of twelve and sixteen, many woodwork exercises will be found of use in connection with garden work. The woodwork exercises given in this volume represent work which has been done by boys of the above ages. These exercises are not arranged in order of constructional difficulty, as they had to be placed to suit the text, but the drafting of a graduated scheme of woodwork for rural schools from the exercises given is quite a simple matter. The general scheme is so arranged that the experimental part of the garden work may form the subject of two years' study, so the number of woodwork exercises included is intended to supply material for the same period of time.

CHAPTER I.

THE CHOICE OF GROUND FOR GARDEN.

1. Slope of ground.—Fig. 1 shows the range of temperature, throughout May 3rd, 1912, of the surface soil at the depth of one inch of three pieces of ground: *A*, sloping towards the sun; *B*, comparatively level; and *C*, sloping away from the sun. Examine each graph and record (1) the average temperature of each soil throughout the time of observation; (2) which soil is warmest; and (3) which is coldest.

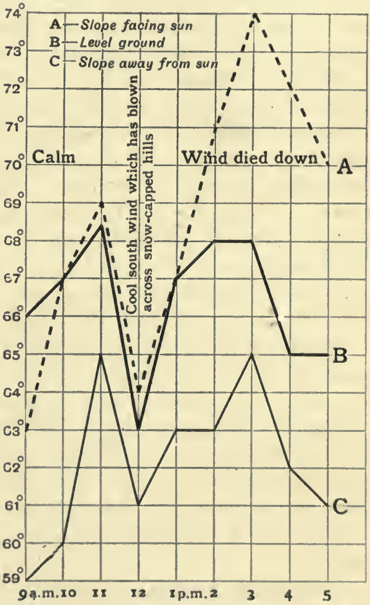


Fig. 1.—Temperatures of different slopes of land.

Arrange two plots of soil, each about 4 feet by 2 feet, the surface of one being level and that of the other sloping from 3 inches or so in front to about 1 foot 6 inches at back. Place a board on end across the foot of each. Pour upon each plot 6 gallons of water from a watering-can, thus imitating as closely as possible the action of rain. Note the result upon the surface soil of each plot. What kind of soil has been washed down against the board at the foot? If seeds had been sown in this plot previous to the watering, what harm would the shower have done?

2. Type of soil.—Examine the plants which grow on the ground available for garden-land. Can you find a part where sedges, rushes, or orchids are common; and another where chickweed, ragwort, oats, or potatoes grow? If so, on a dry day sink a thermometer about 4 inches into the soil in each case, shielding the thermometer from the direct rays of the sun—by surrounding it with brown paper gummed or pinned into a roll and open at both ends, or with the longer part of its own case. Take a handful of each soil and examine it. Which is drier? Is either sticky? Take a barrowful of the wet soil, and spread it in the sun till it is dry. What change do you notice now? Having placed this dried soil in a heap, take its temperature as before. What do you now find? What, then, caused it to have a lower temperature before?

3. Type of subsoil.—If a choice of sites for your garden is possible, dig a hole in each site until the dark surface layer of soil is passed. Does this surface soil end abruptly, or does it gradually change into soil of a different colour? Of what colour is the earth you now dig out? This is called the **subsoil**. Rub a handful in the palms of your hands. Does it feel sticky? Does it contain many stones?

Take a tobacco tin; punch a series of small holes in the bottom; and then pack tightly into the tin to the depth of about one inch some of the subsoil in a damp condition. Now pour into the tin a little water. Does any drip through the holes in the bottom of the tin? If not, pour in some of the surface earth. Where does the water lie now? What influence have you seen, by a former experiment, this has upon the temperature of the surface soil? Do you consider such a subsoil would be very suitable for your garden? Why?

Empty out the tin, and punch in the centre of the bottom a hole just large enough to allow a piece of glass tubing open at both ends to pass through for an inch or so. Fill up with subsoil as before to the surface of the tube, taking care not to plug the upper end of the tube with subsoil. Fill in the soil as before, and pour on water. Does the water pass through now? What effect would this have upon the wetness and coldness of the upper soil? Does this suggest to you a method of getting rid of the water in the soil which renders it too wet and cold?

4. Protection from winds.—Find out from the weather record of your school, or, if this is not to be had, from a local gardener or some one suffering from rheumatism, which winds blow with greatest frequency during February, March, and April—the months of the young buds. Are these winds attended by cold or warm weather? What suggestions would you make with regard to preventing these winds, if cold, from striking upon the young plants of your garden?

Take a large tin can with a lid, both being watertight (a large pitcher and lid will do quite well). Fill the lid with water and put an equal amount into the can. Place both in some spot where they are exposed to the winds already mentioned. What is the result by the end of the day? How is it that the lid loses more water than the can? Does this help you in any way to think of a method of sheltering your garden from such winds?

Choice of ground.—In choosing a piece of ground for a garden, it would seem the simplest way out of the difficulty to have a chemical analysis made of the different soils under consideration, so as to find out which contained in greatest degree the necessary elements of plant food-material, and to decide accordingly. If the soil were regarded merely as a store-room of food-material from which the crop extracts nutriment, as, for example, in the case of the wheat lands of America or Russia, where little or nothing is returned to the soil in the way of manure, this method might possibly be suitable. But, if we view the soil rather as the medium by which the food-material supplied as manure can be rendered fit for plant use, if we consider the soil as nature's cookery department where the raw material is so treated and prepared that the plant can absorb it through its young roots, then much more than its inherent supply of food-material must be considered. We must know whether the soil is capable of dealing profitably with the new supply of raw substances passed into it every year as manure for the use of the plant.

In every place where intensive cultivation in the form of gardening is carried on, the latter point of view is correct, for much more food-material is being applied yearly to the soil than the crop makes use of, and the suitability of soil for gardening purposes must be measured by the ability which the soil possesses for changing this food-material into crop. To express it concretely, it has been found that two soils, which on chemical analysis have been shown to possess almost equal supplies of the materials requisite for plant growth, have, under cultivation and on receiving equal amounts of manure, given a very different return in crops in both quantity and quality, one soil possessing the inherent quality of being more capable than the other of changing the raw manure into readily available plant food-material.

Slope of ground.—This power of the soil depends upon several conditions. No matter how much available material the soil contains ready for the plant, unless the latter receives an early and good start as a seedling, full use of this material cannot be made. Now, in nature, where seeds of wild plants lie dormant in the soil during the cold of winter, and begin to grow only under the genial warmth of spring and early summer, it is evident that a certain degree of warmth is necessary for germination; and, other conditions being equal, those seeds which lie in a position where the sun's rays cause an early rise of temperature in the soil are the first to show signs of awakening life, and the earliest to develop flowers and fruits. The difference in the advance of vegetation at the top and bottom of a narrow ravine shows this well.

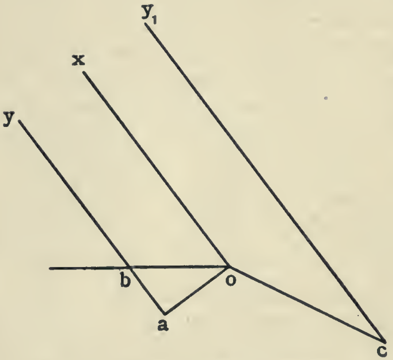


Fig. 2.—Sunlight in relation to aspect of the ground.

Fig. 1 is a graph showing the range of temperature throughout the day on May 3rd, 1912, on a piece of ground at the Gordon Schools, Huntly—the part *A* sloping towards the sun, *B* being practically level, and *C* sloping sharply away from the sun's rays. Fig. 2 shows the cause of these differences. *oa* is a piece of ground sloping south, *ob* is level, and *oc* faces the north. A beam of sunlight, represented as *xy*, heats an area of land represented by *oa* when the ground slopes to the south. The same beam heats the slightly larger area represented by *ob* in the case of level land, and a similar beam, xy_1, heats the considerably larger area represented by *oc* when the land slopes to the north. The result is that the quantity of heating power being equal, the greater the area of land to be heated the less marked will be the rise in temperature.

The natural deduction to be made is that the nearer the slope of land is to a line perpendicular to the rays of the summer sun, the warmer will that land be; but this does not necessarily imply that it will be the most suitable for gardening. Other conditions must be considered. As has already been seen, if the slope is rather steep, the action of rain upon the surface causes the finer particles of soil to be washed down hill from their place, thus gradually removing the best soil of the garden, and at the same time resulting in the displacement of any seeds sown. This process of denudation has been carried on to such an extent in many places as a result of deforestation (*e.g.* many of the Mediterranean lands) that once profitable tracts are now stony wastes. The forests kept the soil in its place, owing to the fact that the leaves of the trees broke the fall of the rain; and the moss and undergrowth acted as a sponge, retaining the water and preventing it from running down hill as a series of small rills.

Almost similar conditions can be seen in our own country, cultivated hill sides being almost bare of soil and bearing poor crops on the higher parts of the slopes, while a little lower down the deeper soil—which has steadily been washed down hill—yields good crops. Consequently a piece of ground which slopes slightly towards the sun is more suitable for a garden than that which has a steep slope.

Type of soil.—If the suitable pieces of ground be almost level, but show distinct differences in the kind of vegetation they bear as mentioned above, then Experiment 2 will show that slope towards the sun is not all that is needed. Marshy land is colder throughout the whole day than is the drier soil which is under cultivation. This is due to the fact that the **specific heat** of soil is low compared with that of water. To raise the temperature of one pound of dry soil by 1° takes only from one-tenth to one-fifth the amount of heat that is needed to cause the same rise of temperature in one pound of water. Hence the more water the surface soil contains, the colder it will be throughout the year, and as a result the less suitable it will be for gardening.

By draining the soil, however, this objection can be removed. But in the case of marshy soil, the earth has during the course of ages become so impregnated with acids carried into the land and accumulating there—owing to want of egress for the water—that such soils need very special treatment and a considerable length of time ere they become suitable for garden cultivation; so that marshy lands may at the outset be discarded. Often, however, when the surface soil is suitably placed and seems on examination free from excess of water, there exists, at the depth of a few inches—sometimes much deeper—a stratum of clay subsoil which, owing to the fact that when wet it is **impervious** to water, *i.e.* refuses to allow water to pass through it, causes the rain which falls to accumulate in the upper soil since it has no means of percolating downwards.

Subsoil.—In such a case it is necessary to drain the land if garden soil is to be obtained which will give the required response to the heat of the sun. Now draining is a laborious business, and unless done well had better not be attempted. In fact, it should not be undertaken unless it be absolutely necessary, and as the operation partakes more of manual labour than of manual exercise, it is of but questionable educational value. The best thing to do when it is found that the ground chosen requires drainage is to employ local labour for the purpose. The best man to advise as to the most suitable method of drainage to be adopted is a practical farmer of the neighbourhood, and while the work is in progress the pupils may with advantage take some part in it for an hour or so each day.

Drainage.—That moisture is absolutely essential for plant growth will be accepted as a truism, and at once the lack of vegetation in desert regions like the Sahara rises to the mind. Owing to absence of water the Sahara is bare of plant growth, yet that the soil is potentially of great fertility is obvious from the fact that wherever the **water-table**, that is, the level of subsoil water, approaches near enough the surface of the ground to form a spring, or at least give a certain supply of water to the upper reaches of the soil, there oases are found and crops grown. But desert conditions with regard to plant life can be made anywhere. Suppose we take some garden soil, spread it out to the air until it is air-dry, place it in a pot which receives absolutely no water, and sow mustard seed in it. Despite the fact that certain conditions favourable to plant growth are present—fertile soil, good seed, and correct temperature—yet for want of moisture absolutely no growth takes place.

But we have just seen that boggy land which contains abundance of water is unsuitable for garden soil, despite the fact that water is perhaps the most essential factor in plant growth. This leads us to the opinion that as in the case of plant food-material in the soil, where the value of the soil to the cultivator depends not so much upon the amount of this material which exists in the soil as upon how much of it becomes available for the use of the plant, so the value of the water-content of the soil must be measured by the same standard. A heavy clay soil may contain much water while a light sandy soil has but little, yet plants may grow well on the latter and may wilt and die on the former. The cause is not far to seek. Plant roots lacking oxygen cannot grow, and if a soil is water-logged, air cannot penetrate deeply through the pore-space. The result is that the roots must feed in the surface layer of the soil, whose store of moisture becomes soon exhausted; and though plenty of moisture exists deeper down in the soil, it is valueless to the plant, as the roots cannot live in the airless deeper levels. But draining of this soil means the carrying away of water from the lower levels, say 3 feet down, with the result that by the force of gravity the water in the upper reaches of the soil percolates downwards; air follows the water and roots follow the air, until plants have a depth of 3 feet in place of a few inches in which to search for water and incidentally for food-materials.

To obtain this result is very important; for even with a rainfall varying from 28 to 40 inches per annum, plants often suffer from drought in summer. A rainfall of 30 inches per annum means over 4000 gallons per plot of 30 feet by 9 feet, and yet in most years there come periods when the garden-worker looks anxiously for signs of rain. This is due to the fact that most of the rain falls during the period when there is no growth, and a large part of it flows away over the land, drains away, or is evaporated. So that the main purpose of many of the operations of the gardener is the conservation of this moisture; and of these operations drainage takes the first place in the laying out of the garden. Drainage is usually looked upon merely as a means of getting rid of superfluous moisture in the soil, thereby raising the temperature and making clay land earlier in sowing and for harvesting, but what has been said will show that it also results in a greater field being opened up to the plant for its search after moisture and food-material by means of its roots.

Bacterial action and fertility of soil.—But drainage has another important result, in that by the admission of air it renders possible bacterial action in the lower reaches of the soil. Dr. E. J. Russell, director of the Rothamsted Experiment Station, Harpenden, has shown very convincingly and very simply that the top layer of garden soil contains a multitude of bacterial life. He took two Florence flasks, fitted them with stoppers and glass tubing as in Fig. 3, introduced a column of water c_1c_1 into the tubing, poured an equal amount of lime water into each flask, and hung in flask *a* by means of a silk thread a bag of moist earth from the surface layer of the soil. The stoppers were forced home until the surfaces of the column of water c_1c_1 were level; these points were marked, and then the whole was placed in darkness.

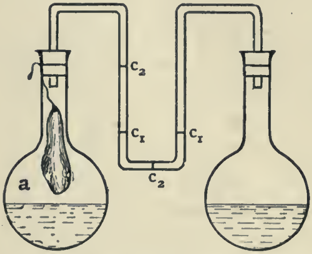


FIG. 3.—Experiment on the action of soil on air.

After a few days, examination showed that the column of water had moved and had taken up a position c_2c_2 nearer the flask *a* in which the bag of soil was hung, showing that the amount of air in flask *a* had been reduced and the column c_1c_1 had moved so as to maintain equilibrium. But the lime water in *a* had turned milky, which is a sign of the presence of carbon dioxide; and when the stopper of *a* was withdrawn and a lighted taper introduced into the flask, it went out, showing that oxygen was not present to support its combustion. All this points to the using up of oxygen and the giving off of carbon dioxide by some living organism in the bag suspended in flask *a*. Examination of the soil used reveals no animal that can be seen, and the conclusion is that the organism or organisms must be so small as to be microscopic. These micro-organisms, which use up oxygen and generate carbon dioxide, are believed to have much to do with the increase of fertility in the soil, so that increase of the depth to which the air has free action means increase of the bacterial processes in the soil, and therefore of its fertility.

Drainage as a rule is unnecessary in the case of light soils, that is, of sands or sandy loams with pervious subsoils. Water percolates freely downwards to the water-table, *i.e.* to where all the pore-space between the minute particles of soil is filled with water, and there is thus no fear of water-logging. In the case of heavy clay soils, where the particles are much smaller than in sandy soils, the surface layer instead of parting with moisture downwards becomes water-logged at the surface, and the water may take months to percolate downwards to the water-table.

The purpose of the gardener, then, is to create what may be called an artificial water-table by means of drains, and in this way to shorten the distance through which the water must percolate, and so hasten the operation. Pipes should be laid at the depth of 3 feet. A greater depth from the surface does not shorten the distance of percolation sufficiently; a smaller depth interferes with cultivation.

Protection from winds.—The question of protection is important. Certain winds, as already shown, are great robbers of moisture, and if it be possible to choose a garden site which is naturally sheltered from such winds by a wood or hill, or by buildings, the opportunity should not be missed. But in the case of a wood, the garden-ground should not be pegged off nearer than ten yards to the trees, else their roots, seeking food-material and moisture chiefly close to the surface, will rob the garden crop. If such shelter is not obtainable, arrangements must be made for protecting the garden by means of a wooden wall, a hedge, or a belt of quick-growing shrubs.

5. The cleaning of the ground.—Arrange to have the ground ploughed over and chain-harrowed. Then carefully gather all weeds you can find, taking care to collect roots especially. What is a weed? Does "a plant growing where it is not wanted" suit as a definition? Can you recognise couch-grass, dock, dandelion, knot-grass, buttercup? Examine these, and explain why it is dangerous to leave any of the underground part of these plants in the soil.

Collect all weeds into an out-of-the-way corner of the garden and make a heap, putting down first a layer of weeds about 6 inches deep, then a sprinkling of lime, then a layer of weeds, and so on until all you have gathered is used. This is called a *compost heap*, for which you will find use later.

The cleaning of the ground.—No matter what kind of soil is chosen for the garden-ground, it is better first of all to have it broken up by ploughing. This plan loosens the ground for 6 inches or so and saves the heart-breaking, back-aching work which the first digging of hard soil entails. Usually it is not impossible so to interest some farmer of the neighbourhood that at a slack time in his farm work he willingly gives the hour or so necessary to plough and harrow the comparatively small bit of land chosen for a school garden.

Weed-gathering over a large area is a painful necessity, but it is only the first of many operations which must be honestly faced and rigorously performed if the garden is to be a success. A quarter of an inch of couch-grass, half of a dandelion root, a little piece of the buttercup called crowfoot, left in the soil to-day means a copious crop of these for next season. (The last-named plant is called "sit-siccar" in certain parts of Scotland—siccar means sure—and a little undesirable acquaintance with it in the garden bears home to one very forcibly the aptness of the name.)

But all these weeds and others can be turned to account by the garden-worker who thinks ahead of the immediate task to be performed, and the compost heap will provide valuable material for the flower-border later. While such weeds should be perseveringly sought for and collected, care must be taken that the turf is allowed to remain on the ground. The top three or four root-bound inches of the soil, together with the grass, clover stems and leaves above ground, are too valuable to be removed even to the compost heap, for they contain much readily available plant food-material. The result of an experiment performed in this connection is shown in Fig. 4.

Pot No. 1 was filled with soil from the surface foot of the school garden; pot No. 17 had soil from the surface foot, mixed with which was one ounce of small pieces of dried leaves, roots, twigs, etc. Mustard seed was sown in each, and the pots were placed under exactly the same conditions with regard to warmth, light, and moisture.

The resultant difference in crop in both healthiness and size is ample evidence of the value of vegetable matter to the soil. Therefore, while all the weeds already mentioned should be carefully removed, the turf must be left on the land, to be disposed of later when digging operations begin.

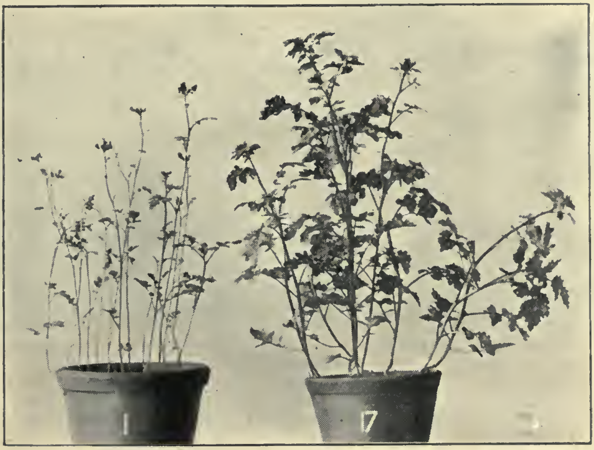


Photo Mr H James

FIG. 4.—Effect upon crop of the addition of one ounce of vegetable matter to soil.

6. Tool-house and potting-shed.—These sheds should be built by the pupils if possible, in which case the suggestions given in Figs. 5 and 6 may be found useful. In any case the tool-house should be completed before the gardening tools are to hand.

The choice of tools.—Experience has shown that so-called ladies' tools are too weak to be of much use in the school garden, and the ordinary sizes of spade and fork are too large, so that the best thing to do is to have special tools made on the ordinary size model. The following sizes of spade and fork have been found excellently suited for the work, and are easily procurable. It is advisable to order two sizes of spade and fork to suit the different builds of the pupils. The number of tools given is for a class of twenty boys working at one time :

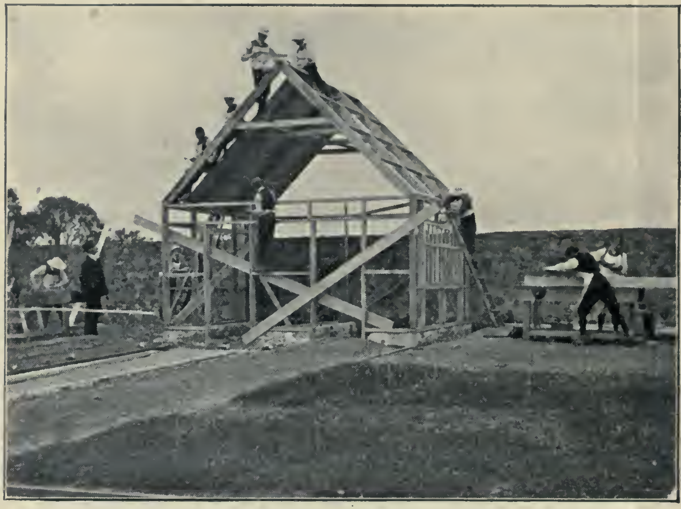


Fig. 5.—Boys building garden-shed, Gordon Schools, Huntly. Beds of cereals, clovers and grasses in foreground.

	Price.		
	s.	d.	
16 Spades, 6½″ by 10½″ blade by 26″ handle ; bright steel,	3	3	each.
4 Spades, 6″ by 9½″ blade by 24″ handle ; bright steel, -	3	0	,,
16 Digging forks, 7″ by 12″, 4 prongs, by 24″ handle, -	2	3	,,
4 Border forks (size 3), 4 prongs, by 24″ handle, - -	2	3	,,
20 Dutch hoes, 4″ broad, - - - - - -	1	2	,,
20 Solid steel rakes, 8 teeth, bright, - - - -	1	10	,,
20 Trowels, - - - - - - - - -	0	7	,,
20 Solid back-draw hoes, 5″ blade, - - - - -	0	9	,,
3 Watering-pans, 2 gallons, - - - - - -	2	6	,,
6 Garden lines, with wrought-iron reels and pins, - -	2	3	,,
1 Spray syringe, 2 roses, 1 jet, - - - - -	7	0	,,
Pruning and budding knives, - - - - -	1	6	,,
2 barrows, special size, - - - - - - -	20	0	,,

These prices, of course, are but approximate.

7. **The other requisites.**—Riddles, riddle supports, weed-baskets, potato trays, dibbles, digging sticks, measuring rods, plant supports, plant labels, name plates, boot scrapers, wooden rakes for levelling, garden frame, etc., illustrations of most of which are given (Figs. 7, 10, 29, 30, 31, 34, 35, 36, 37, 38, 39, 42, 43, 51, 52, 59, 60 and 88), can all be made in the woodwork class. Rake handles should be so marked in feet and inches with black paint that they can be used as measuring rods, and each tool of each set should be clearly marked with a number corresponding to that upon the rack in which the set is kept.

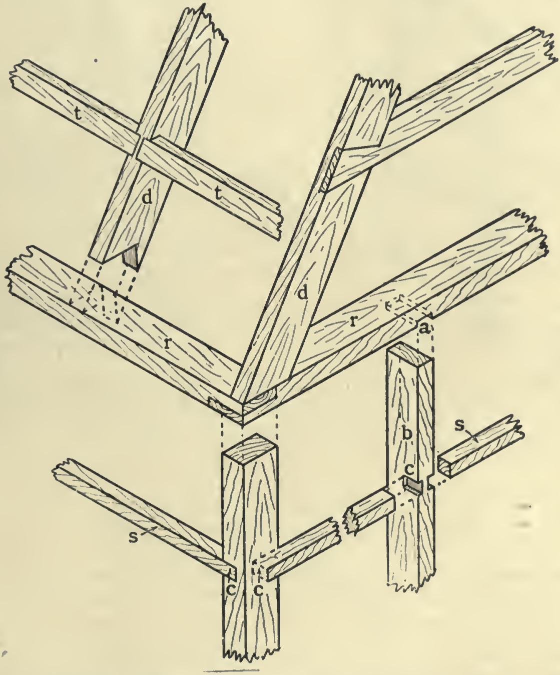


FIG. 6.—Details in construction of tool-house : *a*, slot for side-post ; *b*, side-post ; *c*, corner-post ; *d*, ends of couples ; *r*, top rail ; *s*, side rail.

So complete an equipment as given above, however, is not absolutely necessary where the system of dual plots is adopted and the pupils work in pairs. In this case one spade, one fork, one rake, one back-draw hoe, and one trowel per plot will be found quite sufficient, and the work will not thus be materially hindered, while the initial expense will be reduced by almost one-half. Taking this latter arrangement as a basis, the expense for the equipment necessary for ten plots, *i.e.* twenty boys, should not exceed £12, including the cost of barrow, garden lines, syringe, etc.

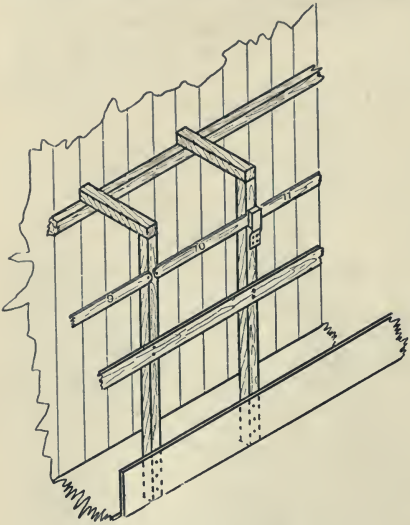


FIG. 7.—Suggestion for tool rack.

Each complete set of tools should have a separate rack for itself (Fig. 7), so that broken or dirty tools can be noticed readily and the owner of the tools discovered.

CORRELATED EXERCISES.

1. Take note of the dates of harvest in wheat, barley, and oat fields in the neighbourhood. Which slope of land has its harvest earliest? Of what advantage is this?

2. Do you expect that the deforestation of hill slopes for the purpose of forming agricultural land would be profitable? Do you know of any countries where this has been done in the past with disastrous results?

3. The river valleys of Mesopotamia and the Nile were in ancient times the seats of the great empires of the world, despite the fact that practically no rain falls there. Can you account for this? Whence came the soils of these valleys?

4. Give a description of the country of Britain at the time of the Roman invasion. Describe the changes resulting from the draining of the land.

5. Make a note of the different pieces of ground in your neighbourhood which are not under cultivation. Can you find a cause for this in each case?

6. Examine trees growing in an exposed position in the neighbourhood. Do lichens grow all over their trunks, or is there a bare space extending from the base upwards? If the trees are firs, do the branches spread out symmetrically from the trunk, or is there a much heavier weight of branches in one direction? Can you associate these facts with the direction of the prevailing cold winds?

7. Make drawings to scale showing front and end elevations, and plan of a garden shed.

8. To a full-size scale make a drawing of the "heel" and "spur" of the couples (*d* in Fig. 6). Calculate the angles at which they must be cut.

9. Estimate the area of the front and back, the two sides, and the roof of the garden shed, taking all measurements from your drawing. If the wood used in its construction be 7 inches wide, how many running feet should be ordered if 5 per cent. be allowed for waste? Find the price at the local rate per running foot.

10. Calculate the cubic content of wood needed for posts, rails, rafters, and couples, and find the price at the local rate per cubic foot.

11. You have already found the total area of wood used. Find the cost of painting the outside of the shed with two coats of paint at 3½d. per lb., each pound doing 6 square yards for one coat.

12. What would be the cost of roofing the shed with corrugated iron, sheets being 7 feet long and 27 inches wide, 3 inches being allowed for overlap? Each sheet weighs 18¾ lbs., and the iron costs £14 10s. per ton.

13. In putting a loft on the garden shed it was found that from wall to wall it measured 15 feet. The partition was found to be 1 foot 6 inches nearer one wall than the other. Suitable wood could be had but in two lengths, 9 feet and 7 feet. Would you order all the wood of one length or some of each? If the latter, state the exact number of lengths in each case. What length of waste wood would you have?

14. Find out from the tradesman who supplies the wood what kind of timber you are using, and from what country it comes. Describe the wood industry of that country. How do you account for the fact that British home-grown wood is very little used?

15. Make out the bill for tools supplied. Allow a discount of 2½ per cent.

CHAPTER II.

LAYING-OFF THE GARDEN

1. Planning.—A school garden must contain a certain number of boys' plots (each 30 feet by 9 feet if possible), a space for fruit trees and bushes, a herbaceous border, an experimental plot, a seed bed, and, if space cannot be found elsewhere, a botanical plot. The entrance path

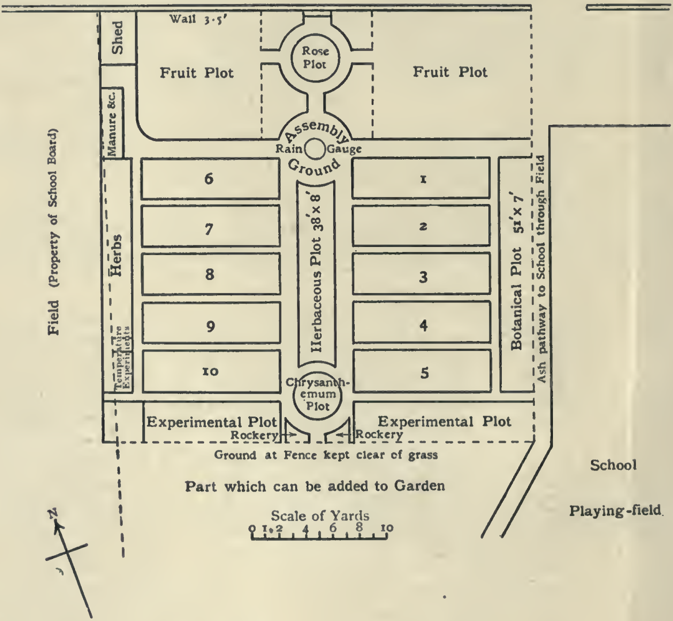


FIG. 8.—Garden, Tain School, Ross-shire.
Designed and drawn by Mr. W. R. M'Cracken, Headmaster.

should be 6 feet wide, all other main paths 3 feet, and those between the plots 18 inches wide. Make a rough sketch plan including all of the above, compare it with other sketches, note the best points in each, and reconstruct the plan, embodying as many as possible of these.

Now make a drawing of the garden to scale, and in the actual laying out take all measurements from this dimensioned drawing.

Planning.—That planning should be done with due regard to the form of the ground and the requirements of the school is of vital importance. The boys' plots are the first consideration, and they ought if possible to be placed alongside each other for purposes of management and comparison, while their breadth should run as nearly north and south as possible, so that equal distribution of sunlight may be given to the rows of plants; 9 feet is the greatest workable breadth, but should it be necessary this may be reduced to six. The space for fruit trees and bushes will be large or small, as the amount of ground available and the suitability of the climate for fruit trees may decide.

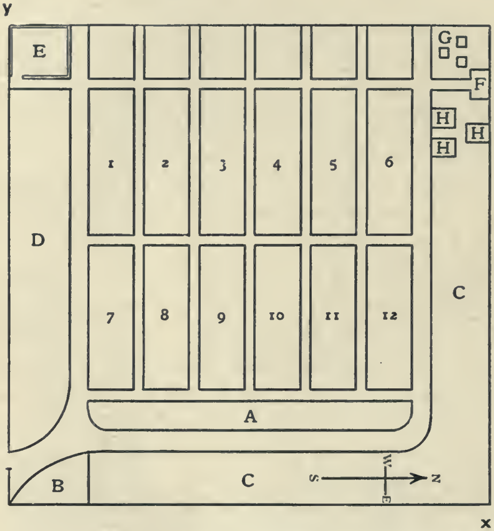
A long, broad, herbaceous border best lends itself to spectacular effect; in fact, the bed should be made 12 feet broad if space permits, while less than 6 feet is useless for the purpose. Indeed, as this is the only part of the school garden which lends itself more to "show" than to educational purposes, if included in the plan it ought to be of sufficient length and breadth to be effective.

The experimental plot should be at least 500 square feet in area; in fact, if manurial experiments are to be carried on, this size is much too small. The seed bed should be placed, if possible, in a sheltered out-of-the-way corner which is open to the sun, and need not be very large—a few square yards are sufficient in most cases.

The botanical plot may be part of the garden if no other ground be available; but the introduction of wild plants into the garden ground—"weeds" so far as the gardener is concerned—is a dangerous proceeding, especially if little, or no, care can be taken of the garden during the summer vacation. In addition, considerable difficulty is usually experienced in keeping a botanical border tidy and in order, so that, if ground outside the garden is available, this plot may well be omitted in drawing out the plan. Of so great importance is it educationally, however, that provision for it should be made wherever a school garden is being laid out.

Specimen plans (Figs. 8, 9, 11, 12, 14 and 19) of different arrangements of school gardens actually under operation are given, and will suggest possible variations in the laying out of the ground.

2. Pegging out the garden ground.—Prepare a number of rough, foot-long, blunt-pointed pegs in the woodwork class. They can well be made from waste wood.



A. Herbaceous border.
B. Rockery.
C. Divided into experimental plots for vegetables, grasses, cereals, plants of economic use; forest trees from seed to 2nd year's seedlings, cuttings, evergreens.
D. Bush fruits, strawberries, herbs.
E. Tool-shed. 14′ × 12′.
F. Summer-house 5′ × 4′.
G. Bee-hives.
H. Garden frames.

FIG. 9.—Garden, Heriot School, Midlothian.
Designed and drawn by Mr. A. F. Ferguson, Headmaster.

Take a piece of wood about 3 inches square in section and about 3 feet long. Point one end and make two saw-cuts in the other end at right angles to each other, as in Fig. 10. This is called a cross-staff.

If the plan of the garden is rectangular, place the cross-staff firmly in the soil at one corner of the garden-ground, taking care it is plumb, the saw cut *aa* pointing along one side of the proposed garden-ground and *bb* along the other. Send two companions to measure from the cross-staff with a tape the required distance in a line with *aa*, and let another worker place a peg at *x* (Fig. 9), the extremity of the line, after you have directed him till the peg is placed in a dead line with *aa.* Then, without moving the cross-staff, similarly place a peg at *y*, at the required distance in a line with *bb* ; remove the cross-staff to *y*, replacing it by a peg. Sight this peg along *aa* and have another peg placed at *z* at the required distance in line with *bb*. Test your pegging out by measuring *xz*.

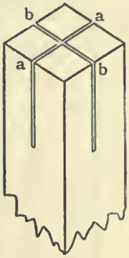


FIG. 10.—Cross-staff.

You have now fixed the boundaries of the garden-ground. The plots must next receive attention. It is best first of all to peg out the main sections rather than to take each plot as it comes. To do this, having first stretched a line tightly along one side of the garden, measure along it, say, to the main entrance ; place a peg, mark the face of the peg which indicates the exact spot, measure the same distance along the opposite side of the garden-ground ; place a peg, and a line thrown across from peg to peg will give one boundary of the main walk. The position of these pegs being exactly correct, measurements from them may be safely taken, all measurements being made from the marked face of the pegs. Should the final measurements show a discrepancy somewhere, you will usually find that the wrong face of the peg has been taken in some cases, and all wrongly placed pegs must be pulled and measurements taken again.

Pegging out.—Extreme care is necessary at every stage of this work. The dimensioned drawing of the garden should be referred to for every measurement, and each distance should be measured twice as the work proceeds, so that no mistakes be made. An error unseen now may make itself evident after the walks have been laid, when it is almost impossible to make any great changes. If the boys' plots are in rows on opposite sides of the garden, care should be taken that the 18-inch paths between the plots are exactly opposite and in line with each other.

3. Laying out of garden-ground.—The paths should receive first care. Stretch a garden line tightly from peg to peg along either side of the proposed walk. Standing on the path-ground, with the back of the spade turned away from you, make a cut in the earth alongside the line from end to end on both sides of the path. These cuts mark the outer edges of the paths. Now dig out the earth from between these cuts to the depth of from 6 inches to 9 inches, throwing the earth on to the spaces which will later be under cultivation. The 18-inch

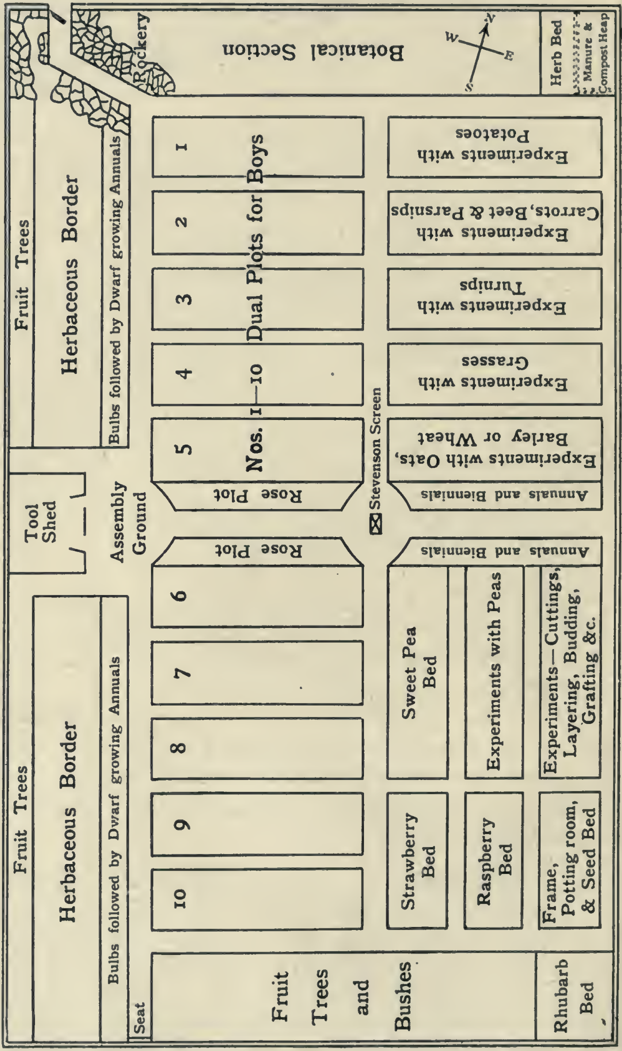


FIG. 11.—Garden, Drumwhindle School, Aberdeenshire.

paths between the plots need not be taken out deeper than 6 inches, while a 6-foot broad path would be all the firmer if excavated to the depth of 12 inches.

Go over the soil you have thrown out, pick out stones, and throw them into the trenches made for the walks.

Laying out.—Unless paths are well made they are a source of constant trouble, and the first essential is excavation to the necessary depth. The narrower the path, in all probability the less heavy traffic there will be upon it, and *vice versa*; so that in the case of a broad main path over which heavy barrow-loads of manure must be wheeled, the deeper and the more solid the foundation is, the better will the path stand the strain.

4. Preparing the soil.—Up to this point the work done has been common to all the pupils engaged in garden work; but now each has a separate plot, the whole care of which is his special business from cultivating to harvesting. The plot in many cases will be 30 feet by 9 feet, a convenient breadth, as will be found later, to be worked by two boys, and if it is in the care of one energetic worker will not prove too large. The boundaries of the plot have already been marked off, and now hard work begins—the hardest and most appetite-increasing work of the garden.

In digging the garden ground, most rapid progress is made when the plots are worked in pairs as *x* and *y* (Fig. 13), and pupils digging must work from opposite ends. Along the breadth of *x*, stretch a garden line at the extreme end of the plot (along the opposite end of *y* a companion will do similarly), measure 4 feet in from the line at either side, and set another line along these marks. Cut the ground alongside the line as was done in the case of the paths, and thus mark off a 4-foot broad space at one end of *x*, and a similar space at the opposite end of *y*. Remove the lines and all is ready. Now digging begins, and the ease or difficulty with which the work is done, as well as the efficiency, or the opposite, of the operation, depends upon how the spade is used.

5. Using the spade.—Grip the top of the spade-handle with the right hand, the palm being directed away from your body, and the hold, while firm, being loose enough to allow the spade to swing freely. Slide the left hand down the shaft, the palm of the hand being above the handle. Hold the spade almost but not quite vertical, at the point where you intend it to enter into the soil; place the left foot on the top of the spade-blade, the position of the latter being close to, and in

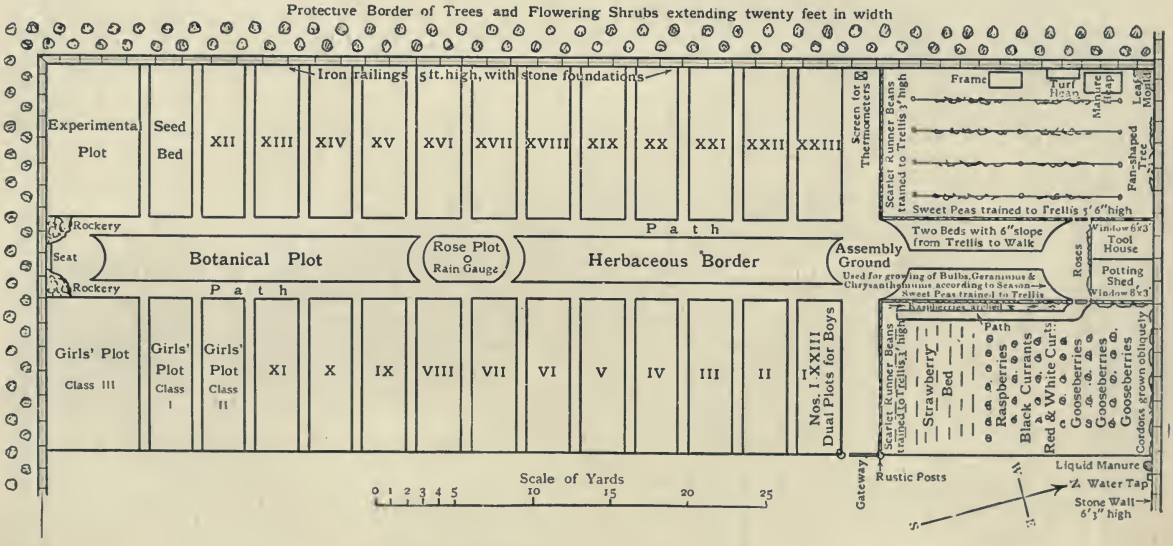


FIG. 12.—Garden, Gordon Schools, Huntly.

front of the heel of the boot, and by using the weight of your body and the muscles of the leg, force the spade into the ground vertically to the full depth of the blade. Pull the handle towards your body, slide the left hand down the shaft almost to the blade, lift the spadeful of earth, and throw it into the required position by a twist of the left hand. The dark surface soil of the first trench to the depth of 1 foot is thus dug out and placed in a heap opposite the end of the plot alongside. Fig. 13 illustrates the succeeding steps of the work.

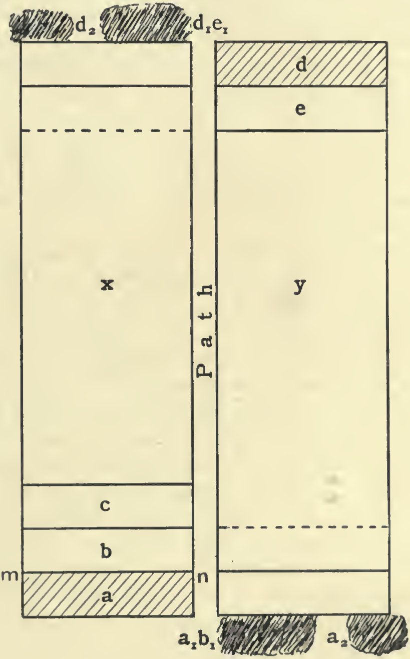


FIG. 13.—Trenching operations.

6. Trenching.—x and y are two plots. The lines drawn across (Fig. 13) are at intervals of 2 feet. Let a_1 denote the surface soil of a to the depth of 1 foot. Then a_2 represents the layer of soil in a, beginning 1 foot deep and ending at the depth of 2 feet. b_1 denotes all the soil of b, from the surface to the depth of 1 foot; b_2 represents all the soil in b, from the depth of 1 foot till the depth of 2 feet is reached. Similarly with c, d, and e. The 4-foot-broad space you have already marked off is represented by the spaces a and b. Dig out the surface soil of x to the depth of 1 foot all over this trench a, b, and throw it to the end of plot y in the position of the heap marked $a_1 b_1$. This leaves you with a trench dug out 4 feet broad and 1 foot deep.

Now from the front of your plot measure 2 feet along the floor of this trench, and cast a line across in the position m, n. This line divides the soil underneath into the divisions a_2 and b_2. Dig out a_2 to the depth of 1 foot, and throw the soil at the end of the plot y in the position of the heap marked a_2. Leave b_2 untouched for the present.

The soil below a_2 will possibly be found of a paler colour than that above, and will be so hard as to refuse easy entrance to a spade. The digging fork, or, if necessary, a pick, is the best tool to use here, and this subsoil should be thoroughly dug and broken up to the full depth of the fork without being removed from the trench in which it lies.

Very large stones should be removed and thrown into the trenches prepared for paths, while if a supply of fallen leaves is to be had easily, especially beech or oak, some should be well worked into the subsoil. Then the turf from the soil already dug out should be gathered from the heap with a fork, and laid, inverted, on the top of the subsoil, while if kainit at the rate of 8 cwt. per acre be spread on the turf it will help to hasten its decay as well as to destroy grubs and wireworms. Above the turf, farmyard manure at the rate of three barrow-loads per plot should be spread, all knots and lumps being thoroughly broken up with the fork.

Now dig out the soil represented by b_2 to the depth of 1 foot, and lay it above the manure which has been laid on the subsoil of trench *a*. This brings you to the subsoil in trench *b*, which should be treated similarly to that of *a*. Then dig out the top foot (c_1) of soil in space *c* and throw it into trench *a* above the second foot of *b*, which has already been thrown above the subsoil of *a*. The second foot deep of space *c*, *i.e.* c_2, is placed above the subsoil in space *b*.

This goes on until, at the opposite end of the plot, a 2-foot broad space is left empty of soil down to the worked subsoil, and in front of that a 2-foot space lacking the top foot of soil. Into the former throw the heap d_2, *i.e.* soil which had been thrown from the second foot in space *d* of plot *y*. This leaves you with an open trench 1 foot deep and 4 feet wide, which must be filled with the soil of heap d_1, e_1, which is the surface foot of soil thrown from the trenches *d*, *e* of plot *y*.

Similarly, the end trenches of plot *y* are filled with soil from the heaps a_2 and a_1, b_1, which had been dug out of plot *x*. All this sounds most complicated, but in practice it is not so if the instructions given are followed carefully.

Throughout the work, remove all stones and throw them into the trenches for paths, while all clods of earth must be broken up with the back of the spade as they are placed in position, save those which are placed on the surface. The surface should always in autumn-digging be left as rough as possible, and never be broken up as is the soil under the surface.

The other plots of the garden, fruit plots, experimental plots, etc., should be trenched in the same manner, the surface being left rough to the action of the winter frosts.

Deep cultivation.—As already implied, moisture, air, food-material, and warmth are the necessary requisites for the good growth of crops, and yet all of these may be present in abundance, but, owing to the condition of the soil, one or more may not be fully available to the growing plant, and a bad crop may be the result. When this is the case, no matter how much labour and expense are expended upon the surface layer of the soil, little or no improvement is evident, and examination usually reveals the presence of a hard stratum of subsoil at a greater or less depth below the surface. This is known as a **pan**, and being practically

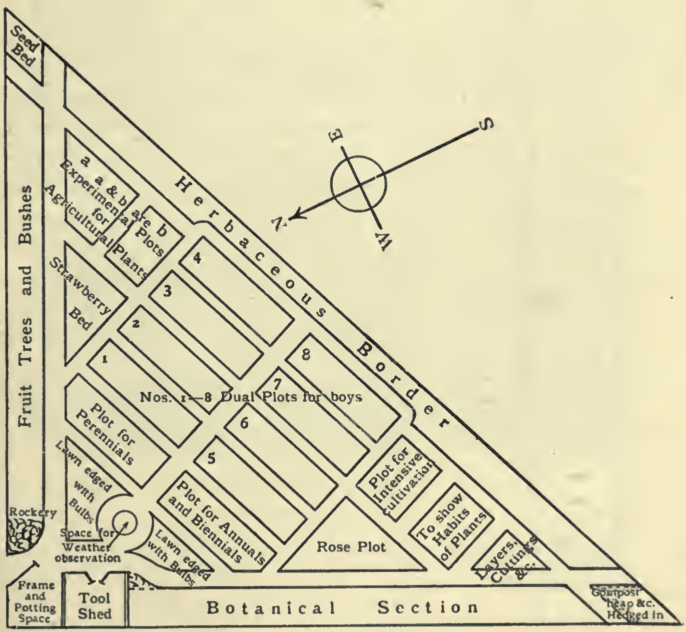


FIG. 14.—Garden, New Elgin School, Morayshire.

impervious to water, is consequently not aerated, and as a result no plant-roots penetrate it. Such a subsoil has little or no communication with the soil above, and is therefore useless to plants. When it is broken up thoroughly and prevented from rapid "panning" again by the introduction of vegetable refuse, water percolates freely, air follows, and the roots of the plants have a greater depth at which to search for moisture and therefore for food-material.

Now, the fact that water percolates downwards from the soil to the subsoil does not necessarily imply that the zone of soil above the water-table, *i.e.* the strata where the pore-space is saturated, does not contain water, for much water will be held in suspension in the soil though the pore-space be not saturated. This suspended water forms a connecting link between the water in the subsoil and the surface layers of the soil, a connection which was not present when an impervious pan existed at a certain depth below the surface; and by means of the pore-spaces this subsoil water is enabled to rise through the soil. In this way the subsoil yields water to the surface layers, an extremely important fact at a time when no surface moisture in the form of rain is available. In an experiment (Fig. 15) three glass tubes, *a*, *b*, and *c*, open at both ends, were filled with air-dry garden soil, sand, and clay respectively, and a piece of linen was tied over the lower ends, which were then just immersed in water. In five weeks the water had risen 27 inches in the garden soil, 15½ inches in the sand, and 17½ inches in the clay.

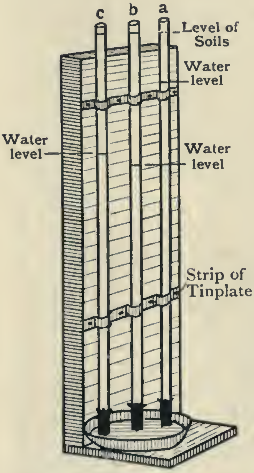


FIG. 15.—Capillarity of soils.

Soil and subsoil.—Gardeners have for ages been agreed that deep cultivation is essential for the best return in crops, and now-a-days few will be found who do not believe that as the subsoil is often sour, lacking in the readily available elements of plant food-materials and therefore less fertile than the surface layer, the former should not be brought to the surface in trenching operations. It is judged a safer method to cultivate the subsoil *in situ*, *i.e.* to apply humus-yielding matter in the shape of vegetable refuse, farmyard manure, etc., to a subsoil which is merely loosened and not brought to the surface, at least until by the decay of this vegetable matter it has to a large extent lost the characteristics of subsoil.

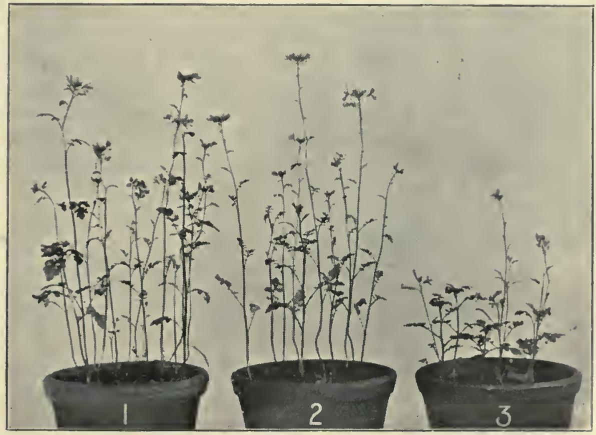


Photo Mr H James

FIG. 16.—Fertility of soil from different depths. 1, top foot ; 2, second foot below surface ; 3, subsoil.

The following experiment showed very distinctly that the subsoil of the school garden in its natural condition yielded poorer crops than the surface soil. Pots 1, 2, and 3 (Fig. 16) were filled with soil from the surface foot, the second foot, and the subsoil of the garden respectively. Mustard seeds were sown in each, and the pots were placed in similar conditions throughout the time of growth. The crop of pot 3 shows that the subsoil is less fertile than are the surface two feet of soil. That the subsoil, however, is capable of becoming good garden soil if supplied with humus was shown by an experiment the result of which is given in Fig. 17.

Pot 3 was filled with subsoil, pot 11 with subsoil plus one ounce of dried leaves, twigs, etc. The difference in mustard crop shows that, by the application of humus-yielding matter, the subsoil of the garden becomes more capable of bearing crops, and might in time, should necessity arise, be lifted from its position to take the place of the present surface soil. At present, however, its inherent capabilities for growing plants are poor, so in all operations great care is taken to prevent its being brought to the surface.

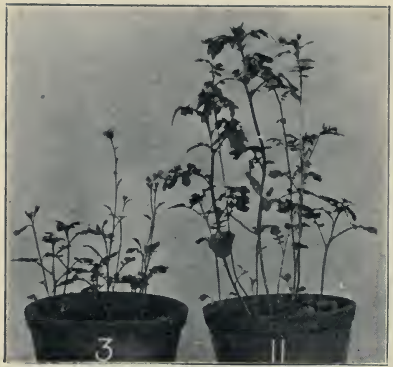


Photo Mr H James

FIG. 17.—Fertility of subsoil increased by the application of vegetable matter.

Humus in the soil.—That the presence or absence of humus is inseparably connected with the fertility or sterility of the soil was further shown by the experiment given in Fig. 18. Pot 12 was filled with river sand, which contains few, if any, of the substances of plant food-material; pot 15 had river sand plus one ounce of dried leaves, etc. Mustard seed was sown in each, and the difference in crop emphasises the conclusion already arrived at; in fact, shows that the application of humus-yielding matter, not only to the subsoil but also to the surface layers of a sandy soil, has good results.

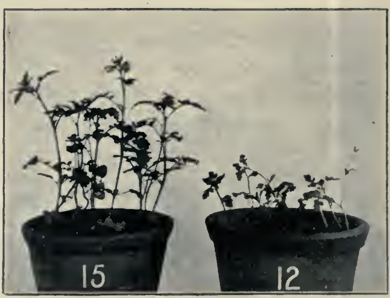


Photo Mr H. James

FIG. 18.—Fertility of fine sand increased by the application of vegetable matter.

The decision to apply vegetable matter to the subsoil, as was done with that in pot 11, was due to the fact that analysis showed that the subsoil of the garden-ground differed greatly from the surface soil in the proportion of decayed vegetable matter present. A difference was obvious at first sight, the surface soil being almost black and the subsoil reddish-yellow in colour. Washing made no difference in this distinction, so burning was tried. A quantity of each was taken, spread out till it was air-dry, and ten grams in each case was weighed out. This amount was then placed in crucibles and subjected to heat until each continued red-hot for some time, the surface soil showing signs of burning while the subsoil merely became red-hot. Each specimen was then allowed to cool, when it was found that the subsoil was still reddish-yellow, little or no colouring matter having been burnt away; while, by the loss of the matter burnt away, the surface soil had become reddish-yellow, and was to all appearance just the same as the subsoil. The colouring matter which had been burnt out of the surface soil is called *humus*, or decayed vegetable matter. The following table gives the results of the experiment, showing the proportion of humus burnt out of each :

Proportion of humus in soils at Gordon Schools, Huntly.

	Colour before burning.	Air-dry weight.	Weight after burning.	Loss in weight.	Percentage of humus.
		Grms	Grms.	Grms.	Per cent.
From top foot of garden soil, -	Almost black, -	10	8·08	1·92	19·2
From second foot of garden soil, -	Brown, - -	10	8·75	1·25	12·5
From field, - -	Brown, - -	10	8·9	1·1	11
From subsoil of garden, - -	Reddish-yellow,	10	9·25	0·75	7·5

Farmyard manure.—In the early treatment of soil which is being laid out as garden-ground, one of the aims of the gardener is to get good "body" into the land. This is an almost indefinable quality, whose presence is most obvious in the mechanical texture of the soil, and is intimately connected with the presence of humus, or decayed vegetable matter. "Body" is most easily obtained in most soils by the application of vegetable refuse in the lower stratum, and of farmyard manure to what may be called the middle stratum of the soil. But farmyard manure is of so variable a quality that a word of advice to the young gardener is here needed. He should not order the necessary farmyard manure without specifying the kind he requires, and knowing the conditions under which it has been stored previous to cartage.

Horse manure is what the gardener terms "hot"—that is, it is subject to more rapid action of bacterial changes, acts more quickly, becomes exhausted sooner, and rises to a higher temperature than is the case with cow manure. For autumn cultivation, therefore, since a quick-acting manure is unnecessary, as the period of growth is still six months away, cow manure is more suited, though many gardeners prefer a mixture. Also, for autumn cultivation fresh manure may safely be used on most soils, but if manure which has already been stored for some time has to be utilised, then the gardener should see to it that he does not purchase from a heap which has been lying loose in the open during the summer, where little or no attempt has been made to conserve the liquid. He should purchase from a man who stores the manure where it is partially covered, well pressed down, not subjected to any turning over, and loses as little of the liquid as possible.

Some gardeners might take exception to the burying of manure to the depth of 2 feet or so, that is down, almost if not quite, to the subsoil; but there is ample reason for so doing, especially in the operation of trenching the soil. If the manure be placed in the upper reaches, plant roots finding food-material close at hand will naturally fail to explore the lower reaches of the soil for nourishment, and so the contents of the lower strata are left unused. But when the manure is buried deeply, a very much larger field comes under the action of the roots, with the result that the full resources of the soil may be taken advantage of. Besides, farmyard manure has the faculty of absorbing a very great deal of the moisture supplied in the form of rain and yielding it up very slowly by percolation. Now, if the manure be close to the surface of the soil, this absorbed moisture will, in all probability, be subjected to evaporation by the heat of the sun's rays, especially in the case of light soils, and passing upwards through the pore-space, be quite lost to the growing crop. The only land to which the application of farmyard manure in the upper reaches of the soil is advisable is clay, for in this case the decay of the manure leaves the soil more open, a result desired above all others by the gardener of such land.

Leaving surface soil rough.—In most districts it is desirable to permit the soil to absorb as much of the winter rainfall as possible, especially if most of the rain falls during this season. As a result of harvesting operations the garden-ground has been well trodden on, and even should it be otherwise, and the surface be left smooth and level, the rain as it falls will flow away over the soil or be evaporated from the surface. Not only this, but the surface, by the persistent beating of the rain, becomes more and more closely packed, until it may form into a kind of pan which is almost impervious to water. By breaking up the land and leaving it rough in early winter, the garden-worker causes the earth

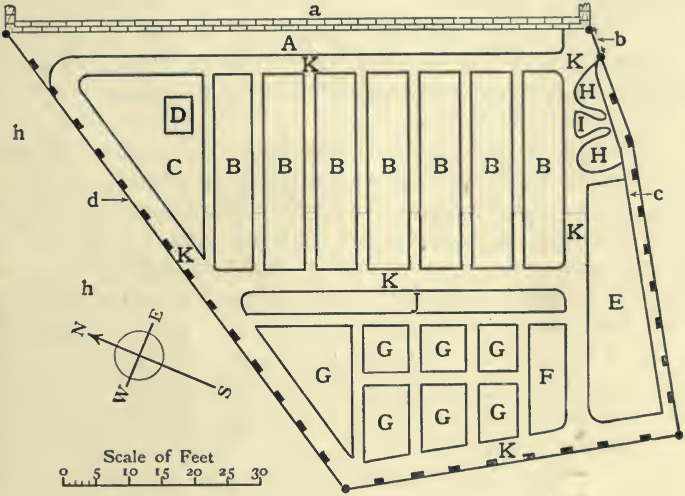


FIG. 19.—Garden, Teanassie School, Inverness.
Designed and drawn by Mr. J. Peace, Headmaster.

A Fruit-trees and bushes.
B. Dual plots. 30′×6′.
C. Strawberry bed.
D. Frame.
E. Herbaceous border.
F. Herb border.
G. Experimental plots.
H. Rockery.
I. Rose plot.
J. Forestry plot.
K. Walks.
a. Stone-wall.
b. Gateway.
c. Privet hedge.
d. Wire-netting fence.
h. Cultivated field.

to present many openings by which rain-water may sink into the soil, while the ground also hinders the flowing away of water by its irregularities. Besides, a loose open soil affords more pore-space than does a close soil, and therefore has greater power of absorption, that is, holds more water in suspension as the rain percolates downwards.

But this result is important in a direction other than the husbanding of moisture in the soil. The water in the soil freezes, expands, and in the act forces apart the particles of the soil, thus making preparation for the free breaking-up of lumps of earth ; and, as we shall see later, performing invaluable work in the way of preparing a seed-bed for sowing time.

Further, as by leaving the surface soil rough a much greater area of soil surface comes into contact with the atmosphere and is subjected to "weathering," a larger proportion of the plant food-material in the soil comes under the same influence, than is the case when the surface soil is smooth and level. Now it will be accepted almost as a truism that the plant can absorb through its roots only such food-materials from the soil as have first been dissolved in water, and chemical analysis has proved that a great deal of the food-material present in the soil is not so dissolved—*i.e.* is insoluble, and may be considered "dormant." But by the action of the atmosphere, frost, etc., much of this dormant material is so acted upon that it can readily pass into solution, and thus become available for the use of the plant.

7. Path edging.—Calculate the length of path edging needed for the whole garden, allow 2½ per cent. for waste, and order the necessary amount of larch railing, 4 inches by 1¼ inches. Specify the number of lengths required 9 feet long, *i.e.* for the ends of boys' plots as well as for any other length which occurs frequently as edging. The wood should be creosoted if possible, but in any case should receive three coats of paint, green or white, which should be thoroughly dry before the work of laying the rails begins.

Posts are needed of two sizes (the larger for junctions), about 2 feet 3 inches long, and these should be pointed, the part above ground receiving two coats of paint, that to be underground being well treated with tar, or slightly charred in a bright fire before being placed in position.

Edges for paths.—Few practical men agree as to the best type of edging to employ. A ribbon of turf, which looks so effective in the private garden, is useless where so many pupils are at work, as it is certain to be broken by being trampled upon. Box and thrift are also out of place in the school garden, no edging looking worse than box made straggly by being rubbed against, except a broken ribbon of turf. Perhaps the most useful edging of all is wood, which, though of no very long life if neither creosoted nor painted, is not so expensive as tiles, and is more suited for the school garden than either box or rough pieces of stone.

The setting of a wood edging is the most difficult of all the operations necessary in the laying out of the garden. A slight warp in a rail often needs careful engineering before it can be brought into line, even three posts in a 9-foot length frequently requiring the additional assistance of a few large stones forced home with a rammer. Over a long length few things look worse than an edging which here and there bulges off the straight, and the work must not be considered finished until all such irregularities have been got rid of.

8. Path making.—The trenches for the main paths should by now have a plentiful supply of stones which have been thrown out of the plots during digging operations. The larger of these should be well forced home with a rammer, so as to make a firm foundation. Above these place the smaller stones, ramming and rolling them down so that the centre of the path is higher than the edges, which should be brought up by stones to within a couple of inches of the level of the cultivated ground.

When the material to be used for surfacing has been decided upon, lay it on evenly all over, so that the finished path is curved in section, the centre being slightly raised above the height of the sides, which should be level with the surface of the garden-ground. Much raking, levelling, rolling, re-levelling, and re-rolling will be necessary before the work is completed satisfactorily;

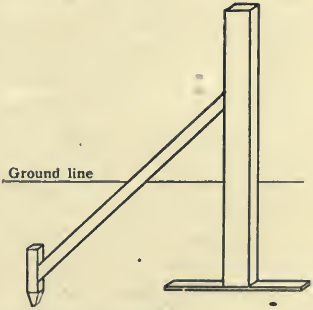


FIG. 20.—Method of supporting corner posts.

but remember that a path well made means no further trouble for years, while an unworkmanlike job results in constant renewal being necessary and an annual condemnation by future generations of school garden-workers.

The paths between the boys' plots should receive a slight bottoming of small stones, and be finished off in the same way as the main walks.

Path making.—This work should be left over until the whole garden has been trenched, partly because all stones dug up are thus utilised, and partly because in this way the cutting up of newly-made paths by the barrowing-on of manure is saved. Every foot of the paths should be well bottomed with stones, and if trenching has not yielded a sufficient quantity, then an additional supply must be obtained, for the stability of a path depends upon its foundation. As to the material to be used for surfacing, local conditions will usually decide. Perhaps the best surfacing to be had is gravel, which is dry in wet weather and cool in summer, while the price is moderate. Indeed, if an available gravel pit is near, the pupils could do all the work save cartage. The finer gravel should be kept for the surface, and if slightly moist when it is rolled-in, it will quickly bind together and become quite hard.

9. Fencing in.—Calculate the length of fence needed to surround your garden. Why is it necessary to fence? If rabbits are common in the neighbourhood would an ordinary wire fence be suitable? How could a wire fence be rendered rabbit-proof? How would a 6-foot close wooden fence be of use for shelter and enclosing? In what way could you utilise it in your gardening operations and at the same time destroy its unsightliness? Suppose a wooden or wire fence is decided upon. Sketch a design. Compare your drawing with those of others and decide which you consider best.

Obtain tar from the gas-works and treat the posts with it to a distance a little above that part which is to be fixed in the earth, leaving the posts for a day or two to dry.

Measure out and mark by pegs the positions of the posts, making allowance for a gate, which should if possible be directly opposite the nearest approach to the school door. What decides the distance you must leave between the posts? In erecting the posts be sure they have sufficient hold in the earth (for a 5-foot 6-inch fence 2 feet 6 inches of hold is not too much), and make certain each post is vertical.

A good plumb line is made by tying a piece of string to a small weight (a stone will suit quite well) and every boy can have one. Stand well back from the post, hold up the end of the string so that the weight hangs in front of you, and see that the post is in line with the string. Nail on the rails, keeping them the same height from the ground all along, and remember that spike nails must be driven across the grain of the wood to prevent splitting. Place uprights in position, each tight up against the preceding one, according to design; and if care is taken that the first is absolutely vertical, the others are bound to be so.

To ensure that their tops are exactly in the same straight line, nail temporarily, an upright every 3 yards along the whole length at the required height above ground, and stretch a garden-line tightly from one end to the other so that it rests on the top of each rail. These uprights, of course, are removed as the work proceeds.

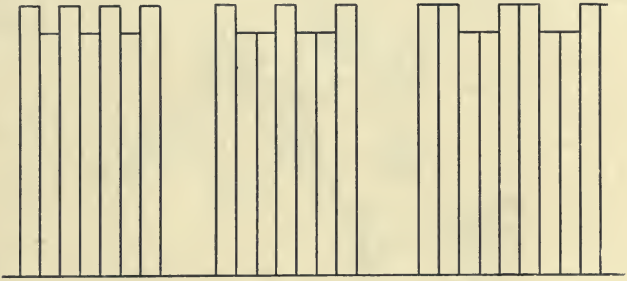


FIG. 21.—Suggestions for plain design for fence.

Fencing in.—Without secure fencing and adequate protection, the work done in the garden is usually profitless, for a cow or a pig of an inquisitive turn of mind and an appetite to which grass no longer appeals, will in a few minutes ruin the work of months, or an icy east wind may blow upon an unprotected quarter and blast a whole year's fruit crop. Fig. 22 shows the effect of such a wind upon the black currants at the Gordon Schools in 1912, only two or three currants surviving out of a whole bunch.

Conditions are most satisfactory when fencing and sheltering are obtained by one operation, and for this combination nothing can compare with a high stone or brick wall. No wind screen is more effective, no garden in a district bears earlier fruits, than a walled garden with a south aspect, and in no situation are early potatoes and vegetables produced in finer perfection; but the cost renders such a wall in most cases impossible for a school garden. The next best then is a wooden wall. This should be about six feet high, be built of old railway sleepers or larch if possible, and be topped by a strand or two of barbed wire. Fruit trees and bushes find their most suitable situation close to the wall, so the boards should be free from bark in order to present no crevices for insect life.

Should a wire fence be decided upon as being cheaper, the lower part at least should be wire-netted, while as a protection from winds a broad belt of quick-growing trees and shrubs should be planted all round, being kept at least 10 feet from the edge of the garden-ground to prevent the robbing of the soil by their roots. Deciduous trees and shrubs should not be wholly employed, but some evergreens intermingled, so that shelter is provided in winter and early spring, when the former are leafless. Plants also should be so selected that the belt may be of educational use from a botanical point of view.

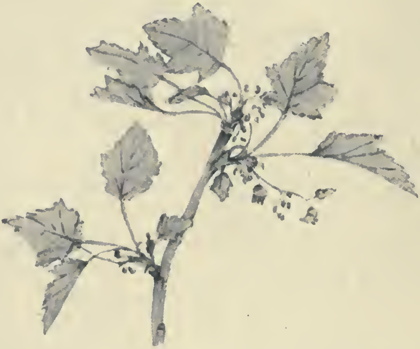


FIG. 22.—Result of a cold east wind upon young black-currant fruit. Only three fruits on the spray are uninjured.

A hedge as a protection from weather and animals is not to be despised, though it cannot compare with a wall. Quick, privet, holly, and beech are all serviceable, but a hedge has two objections: it usually takes too long to grow, and when full grown is apt to become ragged and open at the base. In addition the roots act the part of robbers. However, should a hedge be decided upon, a temporary wire fence must be erected as well, and the hedge-border, *i.e.* the soil for a distance of a couple of feet or so on either side, should be kept absolutely free from weeds.

CORRELATED EXERCISES.

1. Calculate the area of the garden. What fraction of an acre is your plot? Find the rent of your plot at the local rate per acre.

2. At the Huntly School garden the hourly temperatures on either side of the path leading to the garden shed (for direction of path see Fig. 12) on 4th May, 1911, were:

Hour.	East side.	West side.
	C.	C.
9 a.m.	14°	22°
10 ,,	17°	28°
11 ,,	19°	31°
12 ,,	20°	32°
1 p.m.	25°	33°
2 ,,	27°	26°
3 ,,	29°	20°
4 ,,	27°	19°
5 ,,	20°	17°

Tulips on the west side were in bloom eight days before those on east side.

Find the average temperature on each side. Can you account for the difference? In what way does this explain to you why the rows of plants in the plots should run as nearly north and south as possible?

3. Does spade-cultivation play a very important part in the agriculture of Britain? Why? Can you name any parts of Britain where the land is cultivated almost wholly by means of the spade and fork? What are the products of these parts?

4. How do you account for the fact that in certain parts of France the surface few inches of black soil is considered the personal property of the peasant-proprietor cultivating the ground, and in removing from his holding he is legally entitled to carry this part of the soil with him?

5. Kainit is applied to the buried turf at the rate of 8 cwt. per acre. How much per square yard is this? Calculate, fill up, and keep for future use the following table :

Cwts. per acre.	Lbs. per plot. 30 feet by 9 feet.	Ozs. per sq. yard.
1 cwt.	$\frac{3}{4}$ lbs.	$\frac{3}{8}$ ozs.
2 "	....	....
3 "	....	....
4 "	....	....
6 "	....	....
8 "	....	....
10 "	....	....

You will notice, of course, that the fractions given in the first line of columns 2 and 3 are merely approximate, so that the weighing-out may be simplified and the quantities as nearly correct as possible.

6. Over-wet land in Britain is unsuited for agricultural purposes, yet rice is sown when the paddy fields are covered with water and the cultivator in Egypt floods his fields. Can you explain how both of these statements can be true?

7. How is it that the soil of an old garden is darker in colour than that of the field of which it used to be a part?

8. What do you know about "black soils" and "prairie lands"? Where do they occur? What are their characteristic crops?

9. A piece of garden-ground left unworked in early summer soon bears a crop of weeds. The subsoil thrown from the digging-out of a well remains bare of vegetation for quite a long time. Can you explain how this comes about?

10. Find the total price, at the local rate, of the wood used for path edging. What is the cost per running yard?

11. Find the weight of wire for a five-strand wire fence round the garden, allowing 6 feet off for a gate, and considering that 5 per cent. of the wire is used for connection with the corner posts. One cwt. of the wire measures 700 yards, and the cost is 10s. 6d. per cwt.

12. Three strands of barbed wire are put all round the garden. If a mile of the wire weighs 440 lbs., what weight must be ordered?

CHAPTER III.

THE TIME OF PREPARATION.

1. Winter work in the garden.—Winter is drawing on, and your tools will be but little used for a month or two. You have, of course, carefully cleaned off all earth and thoroughly dried them at the end of each period of work, so that now they are quite clean and bright. But during winter damp will cause them to rust unless they are oiled. This is best done by having a well-oiled cloth hung in your tool-rack, and giving a thorough rub-up to all your tools now.

This is the time also of preparation for the coming season. Complete the fitting-up of the tool-house and potting-shed, and should trellis work be necessary for separating off, say, the fruit plot, now is the time to erect it. Paint all the laths before placing them in position, otherwise the wood where the laths cross will soon rot, as it is impossible to work-in the paint in these places after the trellis is complete.

Unless the water-supply is within reasonable distance of the garden gate, arrangements should be made to have it brought near by a pipe if possible. To have a pump inside the garden is a mistake; too much space is needed around it, and its vicinity is apt to become muddy, so that just outside the garden gate in a screened corner is the best position. If it can be hidden by means of a hedge, so much the better

Should it be impossible to convey water by a pipe to the garden, a well should be dug. For you to take a share in the work would not be advisable, as it is mainly manual labour and may be dangerous if the water-table be low, but you should watch at what depth the workman strikes the water-table, and thus ascertain what distance the subsoil-water must rise by capillarity if it is to be of benefit to your crops in summer. The well should be built up inside and have a pump over it, while a couple of old barrels cut in two will provide four tubs into which the water can be run previous to its being used.

Obtain another barrel, fit one end with a hinged lid, and if the pump-water is not used for drinking or cooking purposes, sink the barrel in the ground close to the pump. This you will later use in the making of liquid manure.

Winter work.—Too often the young and the experienced gardener as well, act on the assumption that with harvesting and trenching, work is over until seed-sowing time next season. But the truth is, that the success of the coming year's work is very largely dependent upon the preparation made for it now. The successful gardener puts a deal of thinking into his work, and a large part of his deliberation is done during the winter months.

A good worker always sees to it that his tools are in the best possible condition; to a poor workman the very best tools are bad—largely because he does not do them justice. A spade left wet and soil-clad now will be a most ineffective instrument to work with three months hence, for by the action of the oxygen of the atmosphere upon the damp steel, a process akin to burning is set up and the steel rusts. The fact that this results in a general wasting away of the spade-blade is bad enough, but when to this is added that not only is the spade thereby rendered less keen-edged and more slow in action, but it also looks wofully dilapidated; want of care of his tools must be considered almost criminal in any workman. A broken tool also should never be stored in such a condition. All repairs, however, may be left over until winter time, when such work must be performed before any of the woodwork exercises given are attempted.

Well-water should never be carried straight from the well and applied to growing crops. Being drawn from such a depth, its temperature is much lower than that of the atmosphere, and lower also than that of rain as it falls upon the soil. It would thus tend to lower the temperature of the plant surroundings, and consequently hinder growth. Besides, such water has had no free exposure to the atmosphere, and is therefore lacking in certain qualities which rain-water possesses.

2. Weather observations.—Begin now to take the maximum and minimum thermometer readings, if it has not previously been your custom to do so. Note the gradual lowering of both as winter closes in. Can you associate the decrease of activity evident in the growth of plants with the fall in temperature? In what parts of the world is the temperature so low during by far the greater part of the year that growth of plants ceases wholly? What, then, is obviously the cause of this period of rest on the part of plants?

Should snow fall and lie for some little time, clear it away from some part of your garden plot, dig out the soil for a couple of inches or so, and with a thermometer take a series of hourly readings of the temperature of the soil and of the air during a period of frost, and also while the subsequent thaw is in progress, covering up the exposed part with snow after each reading. Record (1) the daily range of temperature of the atmosphere, (2) the daily range of temperature of the soil under the snow, (3) the difference in range. What useful purpose does the snow play in the economy of plant life?

Examine the clods of earth on your garden plot during a period of frost following after rain. Handle a few clods, and note how the soil water has been frozen. What effect has this on such lumps of soil?

Begin taking the daily barometric reading. A home-made barometer, largely because you have had the constructing of it, is very much more interesting than a bought one, and will give readings quite accurate enough for your purpose.

At the same time use a rain-gauge (a home-made one if necessary), and keep a record as advised below, noting the direction of the prevailing winds as well. Keep all your observations on a chart like Figs. 32 and 33, or arrange them in some manner so that you can note variations at a glance.

Weather observation.—In many cases, only after his best-laid schemes have sadly miscarried as a result of a night's frost, a cold east wind, or an untimely hail-storm, does the young gardener realise how large a part weather plays in the success or failure of garden work. The experienced gardener is well acquainted with local weather signs (even should he use few or no instruments to help him), and makes his plans accordingly. Such knowledge is not to be acquired in a month, nor yet in a year, nor can the careful reading of books on weather take the place of actual daily observation for the purpose of arriving at an acquaintance with local conditions.

The chart (Figs. 32 and 33) is for one month only, but if a series of these be kept for a year and hung up in line, a deal of useful information for a garden-worker can be had at a glance. A mere arrangement of numbers is useless for the purpose, and should the given type of chart not be adopted, care must be taken that the method of recording chosen is both graphic and readable without much close inspection. Mere observation-taking and recording is of little use unless the habit be acquired of noting the result or accompaniment of certain phenomena, of tracing a connection between observations taken, and of formulating general rules from the recurrence of certain results from certain conditions. All this becomes possible only as a result of many observations extending over a number of months, but at the close of each month a number of statements should be drawn up from an examination of the record of the weather experienced during that period. Thus, at the end of six months or a year, the laying down of general laws regarding local weather conditions is rendered more possible and can be done more expeditiously.

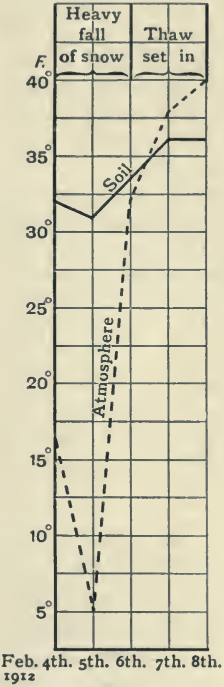


Fig. 23.—Effects of a covering of snow upon the temperature of the soil.

Fig. 23 is a record of the range of temperature of the air and the snow-clad soil at the depth of 3 inches during a part of February, 1912, when the temperature of the atmosphere varied from 5° F. to 40° F., and the soil only from 31° F. to 36° F. Owing to the fact that snow is a bad conductor of heat, the covering of snow acts as a blanket preventing the escape of the warmth of the soil into the atmosphere, and the result is that plant roots are not subjected to so great cold as they would have been were there no snow covering. What is of equal consequence, they do not suffer such great extremes, such as being now cooled below freezing-point and again heated almost to the temperature when the flow of sap and consequent growth become possible.

3. Method of cropping.—Decide what crops you intend to grow on your garden plot. In this you will of course be influenced somewhat by local conditions, but the accompanying plan of cropping (Fig. 24) includes most plants which will find a place in your plot. Potatoes occupy most ground, as they are the staple crop in most cottage gardens, while lettuces and radishes share a row between them, as the former do well when transplanted, and a very early crop of the latter can be caught between the rows of late potatoes. The given plan of cropping shows the distances between the rows of plants which have

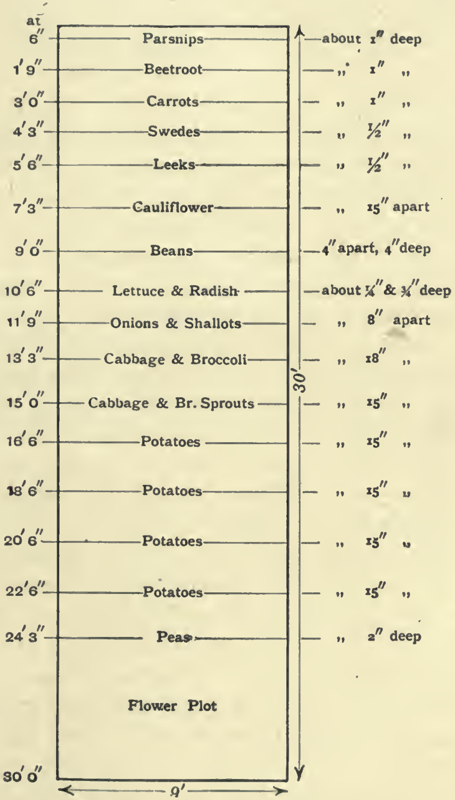

at 6″ — Parsnips — about 1″ deep
1′ 9″ — Beetroot — „ 1″ „
3′ 0″ — Carrots — „ 1″ „
4′ 3″ — Swedes — „ ½″ „
5′ 6″ — Leeks — „ ½″ „
7′ 3″ — Cauliflower — „ 15″ apart
9′ 0″ — Beans — 4″ apart, 4″ deep
10′ 6″ — Lettuce & Radish — about ¼″ & ¾″ deep
11′ 9″ — Onions & Shallots — „ 8″ apart
13′ 3″ — Cabbage & Broccoli — „ 18″ „
15′ 0″ — Cabbage & Br. Sprouts — „ 15″ „
16′ 6″ — Potatoes — „ 15″ „
18′ 6″ — Potatoes — „ 15″ „
20′ 6″ — Potatoes — „ 15″ „
22′ 6″ — Potatoes — „ 15″ „
24′ 3″ — Peas — „ 2″ deep
Flower Plot
30′ 0″
30′
9′

FIG. 24.—Suggested plan of cropping.

been found most suitable for the production of good crops. Omit a row altogether should its inclusion result in overcrowding.

Vegetables should not take up the whole plot, for half the joy of possessing a garden results from the flowers grown.

Draw a plan of your plot to scale, show lines as in the diagram to represent each row of plants, write in the names, and dimension your drawing.

Rotation of crops.—We shall find later that in an ordinary soil under cultivation there is ample food-material for about 100 crops, yet experience has shown that in farming the growth of the same crop in the same soil year after year, sometimes in a few years, sometimes at the end of a much longer period, results in a very marked decrease in the weight of crop at harvest time. The explanation which first suggests itself is that each season the crop withdraws more of the soluble food-material from the soil than is renewed by manuring, by weathering, and by nitrifying bacteria, etc. This seems but part of the truth, as a very large part of, say, the phosphoric acid supplied by phosphatic manures, is precipitated soon after it is applied to the ground, with the result that much of this food-material remains in the soil at the end of the growing season. Besides, even although the full necessary amount of nitrogen, phosphorus and potassium which the crop requires be supplied in the form of manure, still there is a marked falling-off in yield if the same crop be continued to be grown.

This might be explained in the case of "strawberry sickness" in the garden, and of "clover sickness" in the field, by the fact that with these crops stirring of the soil to any extent is impracticable, and therefore the action of weathering and of bacterial life, with the accompanying enrichment of the soil, is lacking; but when it is found that after the lapse of a number of years swedes or potatoes are subject to the same law, despite cultivation, other or at least additional reasons for the decline in crop must be sought.

The subject is one upon which definite information is lacking; and laboratory experiments can but result largely in theories, for the soil is not a simple but a complex mixture of bodies, and the production of similar conditions in the laboratory has not yet become possible. Besides, many agents—mechanical, chemical, and bacterial—must be taken into account. The decrease of crop may be due partly, then, to the cause already mentioned; possibly in part to the excretion of certain poisonous substances by the plant-roots; possibly in part to the action of bacteria on plant-remains left in the soil; but in any case it must be accepted as a fact that the growth of plants brings about such a change in the soil as renders it unfit for the continued production of good crops of any one plant.

In farming, the principle has been recognised for years, and the farmer has adopted rotation of crops as a corrective. For example, by the well-known old-established Norfolk rotation, turnips are grown the first year, barley the second, clover the third, and wheat the fourth, on the same portion of his land. But the gardener's crops do not readily divide into four exactly different kinds of plant, for potatoes usually take up the greater part of the ground, while a very small section is usually sufficient for radishes and lettuces. But by dividing his crop into tubers (potatoes), taps (carrots, beet, parsnips), and fibrous-rooted plants (greens, peas, turnips, etc.), the gardener may be able to arrange a workable rotation for his ground.

Garden rotation.—In a plot 30 feet by 9 feet, where 5 feet by 9 feet is devoted to flowers, it is difficult to make an exact division of the remainder of the plot into three parts to suit the above rotation, but some may prefer to attempt so to arrange their cropping that this may be possible. Such an arrangement is markedly beneficial, however, only when accompanied by deep culture and suitable manuring. Were the land trenched every year and farmyard manure dug-in 2 feet deep, such division into three parts might not necessarily influence the manuring, but trenching need come but every four or five years at most, and during other years the farmyard manure is buried but 1 foot deep. Now certain plants (fibrous-rooted) need much farmyard manure, some (tubers) only a small amount, and others (taps) none. Thus, for the first year, by dividing the vegetable part of the plot into three parts, A, B, and C, A bearing fibrous-rooted plants, B tubers, and C tap-rooted plants, A for the first year receives much farmyard manure, B little, and C none. The accompanying diagram explains the cropping and application of farmyard manure to the plot throughout a three years' rotation.

	1st Year.		2nd Year.		3rd Year.
Much farmyard manure.	A. Fibrous-rooted.	Little farmyard manure.	A. Tubers.	No farmyard manure.	A. Tap-rooted.
No farmyard manure.	B. Tap-rooted.	Much farmyard manure.	B. Fibrous-rooted.	Little farmyard manure.	B. Tubers.
Little farmyard manure.	C. Tubers.	No farmyard manure.	C. Tap-rooted.	Much farmyard manure.	C. Fibrous-rooted.

The practice at the Gordon Schools, however, is to apply a moderate dressing of farmyard manure to the whole vegetable part save that to be under tap roots, supplementing with artificial fertilisers and lime as will be described later.

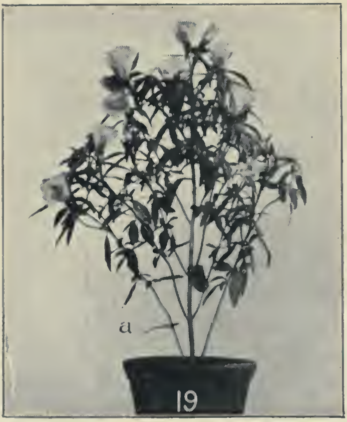


Photo Mr H James

FIG. 25.—One godetia plant grown in a pot. (Note the development of side-buds into bloom-bearing branches.)

Plants need light, air, and root-room.—Figs. 25 and 26 show the result of growing one godetia plant in one pot and twelve in another pot of the same size, placing them under exactly the same conditions otherwise. Not only is the plant in Fig. 25 much healthier looking than are those in Fig. 26, but the crop of the former has a much better general appearance than that of the latter. There is also a very marked difference in the size, beauty, and number of flowers produced in these pots. Pot 20 had only nine blooms, while pot 19 grew eighteen.

This difference is due to several causes. In the first place, the plants in Fig. 26 had no room to branch out and ran to height, which tendency was increased by the sunlight being obscured on account of the overcrowded condition of the plants. Fig. 27 shows this lack of branching-out very markedly in the case of the overcrowded plants. The best plant in Fig. 26 was retained, all the others being removed. It will be noticed that in no case did the side buds of the plant shown in Fig. 27 develop into branches, while in Fig. 25 each side bud grew out into a bloom-bearing branch. Weak growth was thus encouraged in pot 20, and the fact that the close-set foliage did not give free passage to the air to play about the leaves of the plants, while in addition many plants were competing for the available food-material in pot 20, which in pot 19 went to supply the needs of one plant, helped rather to increase weakness than to fortify the plants.

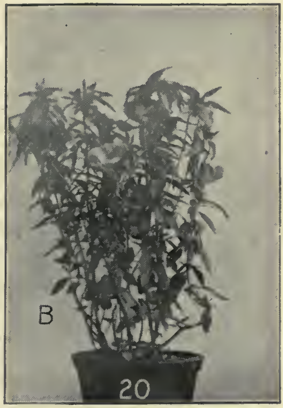


Photo Mr H James

FIG. 26.—Twelve godetia plants grown in a pot.

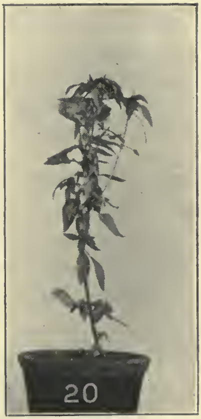


Photo. Mr H. James

FIG. 27.—The best single godetia plant from the group in Fig. 26. (Note the lack of development of side-buds.)

All this goes to emphasise the need for enough room for the plant to grow, and points to the necessity of giving plenty of space between rows of plants in drawing out the plan of cropping.

4. **Seed order.**—This is the time to make up your seed order, and place it in the hands of a good seedsman. Calculate, from the quantities given below, how much seed of each kind is needed for the whole

garden ; carefully write out the order, keep a duplicate, and forward a copy to the seedsman.

The amount of seeds, plants, etc., required annually for 12 plots, 30 feet by 9 feet, would be approximately :

¾ lb. Early peas.
¾ lb. Late peas.
1½ lb. Broad beans.
1 oz. Leek.
1 oz. Turnips or swedes.
½ oz. Onions or 6 lb. shallots.
½ oz. Parsnip.
½ oz. Carrots.
½ oz. Tap-rooted beet.
½ oz. Early globe beet.
¼ oz. Lettuce.
2 oz. Radish.
100 Early cabbages.
100 Late cabbages.
50 Cauliflowers.
25 Brussels sprouts.
25 Broccoli.
1 stone First-early potato.
2 stones Main-crop potato.
1 stone Late-crop potato.

Making up the seed order.—A gardener may make the mistake of being a little early in some operations, but in the matter of making up his seed order it is hardly possible to err on the early side. Later in the season the practical work of the garden will occupy so much of the available time that the seeds are apt to be forgotten until the last moment, with the result that poor seed and even poorer plants are all that can be had. The only remedy is to order early, and request the seedsman to forward seeds and plants by a certain date, at least a fortnight before the usual sowing time of the district.

But a great deal depends upon the choice of a seedsman. The question of honesty apart, a reputable firm cannot afford to sell bad seed, while a small dealer can. However, if it is possible to find out the name of the wholesale firm from which the local dealer buys, the purchaser can decide for himself as to whether he should place his orders locally or not. The proof of the seeds is the growing of them, and one experience of bad seeds is usually enough for any gardener.

Flower seeds.—Annuals should not be neglected in the school garden, and especially during the first season they will be found invaluable, as it is wellnigh impossible to fill up a large space with perennials and biennials at the outset. A low-growing plant will be necessary for the edges of the plots, and any one of the following will be found effective: *Nemophila insignis*, *Phlox Drummondii compacta*, *Saponaria*, *Alyssum compactum*, *Leptosiphon carmineus*, *Calandrinia speciosa*, *Kaulfussia amelloides*. As an edging for a herbaceous border, *Gypsophila elegans*, though rather tall-growing, has so feathery an effect as it mingles with the foliage of the background that it is well worth trying for one season at least.

The front of the 30-feet plot being decided on, it remains to arrange the remainder of its flower space so that the tall-growing plants are at the back and the less strongly growing further forward. Any seed catalogue of a firm of repute will give most of the necessary information regarding heights, and a selection may safely be made from the following: godetia, clarkia, annual chrysanthemum, larkspur, mignonette, ten-week stock, cornflower, poppy, candytuft, nasturtium.

Biennials should not be omitted from the seed order, for a small quantity of each of the old favourites—sweet williams, wallflowers, canterbury bells, and scabious—will yield sufficient plants to make a brave show if grown in masses, while a few pence should be spared for perennials like lupin, pyrethrum, foxglove, campanula, arabis, delphinium, Iceland poppy, aubretia, carnation, and forget-me-not. Even the beginner will find little difficulty in growing from seed the flowers mentioned in this section, and while he may not cultivate prize blooms, he will at least have the satisfaction of possessing a well stocked flower plot during the greater part of the year.

CORRELATED EXERCISES.

1. Explain how tools rust, the effect of rust upon the tools, and how they may be rendered rust-proof.

2. The garden well is 12 feet deep and 7 feet in diameter. The water stands 4 feet 6 inches from the top. If 277 cubic inches of water make one gallon (approximately), how many gallons of water does the well contain?

3. The pump used at the above well is 2½ inches in diameter, has a 7-inch stroke, and is worked at the rate of 5 strokes per minute. Suppose no water to be running into the well, how long would the pump be in emptying out the above water if the area of the section of the pump multiplied by the length of the stroke is equal to the volume of water lifted at one stroke?

4. The length of pipe used to convey water to the garden is 120 feet. The pipe cost 12s. 6d. per cwt. and weighed 5 lbs. per yard. Find the cost.

5. The pipe track for the above pipe was 12 inches broad at the surface, tapered to 9 inches at the bottom, and was 3 feet deep. Find the cost of excavating it at 2s. 6d. per cubic yard.

6. Calculate the amount of wood needed to make a weed-basket. Find the price of 20 such baskets if the wood costs 1s. 6d. per cubic foot.

7. Calculate what depth of snowfall is on an average equal to one inch of rainfall.

8. 277 cubic inches of water measure approximately 1 gallon. Complete the following table from the rainfall given, or, if local readings are available, substitute them for those in the second column:

Rainfall at Gordon Schools, Huntly, 1911-12.

Month.	Inches of Rainfall.	Gallons per plot, 30 feet by 9 feet.
October, - -	3·3	
November, -	6·0	
December, -	3·7	
January, - -	3·2	
February,- -	1·3	
March, - -	2·7	
April, -	1·7	
May, - -	3·1	
June, - -	2·8	
July, - -	2·2	
August, - -	4·9	
September, -	2·7	

9. When the wind veers from east to west, *i.e.* with the apparent path of the sun, warm weather is usually experienced; when from west to east, *i.e.* against the sun, cold weather. Can you explain why?

10. Make up the seed and plant account for the whole garden, and from this calculate the expenditure on these for your plot.

11. Winter has been referred to as the period of plant rest. What is meant by this? How do you account for the fact that this season is taken by nature for the purpose?

12. A seashore district has its fruit harvest earlier than an inland district as a rule. How is this?

CHAPTER IV.

PRELIMINARIES TO SOWING AND PLANTING.

1. When soil may be worked.—Take three pots, *a* containing air-dry garden soil, *b* and *c* garden soil in a wet condition. Work well the soils of *a* and *b* with the hand and replace in their respective pots. The soil of *c* is potted without being worked. Label the pots, and set them aside for three or four days until the soil dries.

Now note the condition of the earth in each pot. What effect has the working had on the soil of *a* and *b*? Judge from the nature of the soil of *c* whether the working or the wetness caused the hard lumpiness of the earth in *b*. Is the soil of *b* such as you have seen gardeners sowing seed in? If not, give a description of the condition of the soil in which garden seeds are usually sown. Do the soils of *a* and *c* answer such a description?

b in Fig. 28 shows the result of working soil in a wet condition. The soil was potted and stored on July 12th, 1911, and photographed on June 28th, 1912. The obvious inferences, then, are that dry soil may be safely worked, but the working of wet soil causes the particles to become cemented together and to adhere in lumps even after the moisture has been quite withdrawn. On the other hand, if wet soil be allowed to lose its moisture in the ordinary course of evaporation without being worked in any way, it crumbles when dry into the condition which gardeners consider most suitable for the surface of a "seed-bed."

Even trampling upon wet ground, and still more barrowing of manure over it, brings about the same effect as working with a spade or fork, for the soil becomes cemented together and dries into a hard cake, which it is almost impossible to reduce to the required tilth for a seed-bed, especially in the case of clay soils.

2. Spring digging.—Carefully watch the weather each day, and should a succession of dry days come, examine the soil with a view to finding out the earliest time when digging may safely be carried on. While a day lost may possibly mean delay of the work for a fortnight, and much loss of moisture by evaporation, the working of the soil even a couple of days before it is in a suitable condition may result in subsequent caking and an unworkable seed-bed later. The former is certainly the lesser evil. The soil is fit to be dug when it does not clog the spade during the operation. If it sticks to the spade, digging should be postponed.

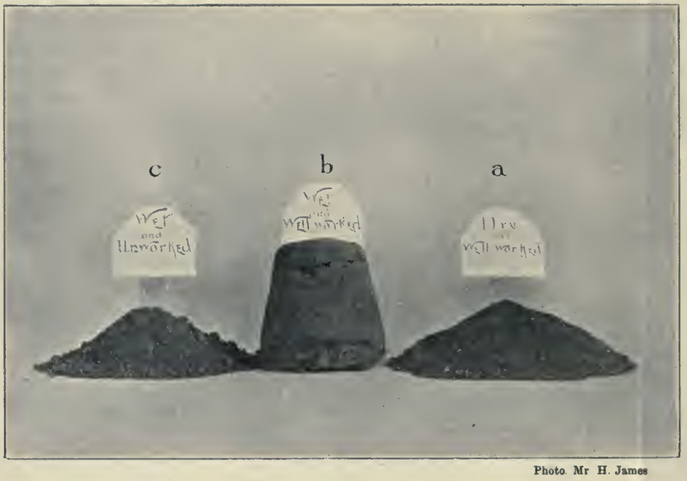


Photo. Mr H. James

FIG. 28.—Effects of working wet and dry soils.

Either fork or spade may be used, but the fork is preferable. Merely shake up the soil lightly, replacing it in the space from which it has been taken, and work no deeper than 6 inches. Do not use the rake, but by the right use of the fork or spade leave the surface as level as possible all over.

It has already been noted that the pore-space in the soil presents innumerable continuous minute passages for the admission of air and moisture, as well as for the ascent by capillarity of water from the lower to the upper reaches of the soil. So long as these passages present an unbroken path for the ascending water, so long will evaporation proceed from the surface layers of the ground in spring and early summer. As the water in the surface layers is withdrawn by evaporation, it is supplemented steadily by that which rises from the subsoil by capillarity. If, however, these passages be broken, if gaps can be made in the water-path so large that the capillary force cannot carry the moisture across, then evaporation will proceed in the layer above those gaps until this layer of soil has been quite robbed of its moisture. This being accomplished, however, evaporation will cease, as the water from the lower reaches cannot make its way to the surface. Much valuable moisture is thus retained in the lower strata of the soil.

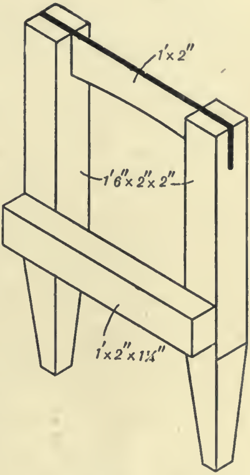


FIG. 29.—Boot scraper. Piece of barrel hoop for top. Material—Larch.

This retention of moisture is effected simply by surface-digging in early spring as soon as the soil is workable. By loosening the soil, the garden-worker creates air-spaces in the surface 6 inches, very large indeed compared with the size of the capillary pore-space by which the water ascends, and across these air-spaces the moisture is unable to pass. Thus the ascent of the soil-water is broken, the surface layer by evaporation becomes practically air-dry, and the soil assumes the characteristics of a good seed-bed.

A second forking necessary.—A heavy shower of rain may, however, beat down the soil until by the filling up of the larger spaces with soil particles the action of capillarity is resumed, and in this case forking must be done all over again. In fact, a succession of forkings may be necessary in a season of periodically heavy rains, but labour must not be grudged if the gardener has made up his mind to deal fairly with the soil and the seed.

3. **When to sow.**—Keep a close watch upon the activities of men who are well known as good gardeners in your district, and if you can persuade one of them to give you a hint of the date on which he hopes to

begin seed-sowing, so much the better. The calendar of garden-work given at the end of this volume may be taken as suited to the requirements of central England, and districts to the north or south will be later or earlier as a matter of course; but two districts only twenty miles distant from each other may have a week or a fortnight of difference in sowing-time, and the loss or gain of this week or fortnight may mean a vast difference in yield when harvest comes. The young gardener might learn the best time for sowing by experience, which, after all, is a most expensive method, and, the moralists notwithstanding, most unsatisfactory in its immediate results. No one can advise so well as the old local gardener, who usually has a soft spot in his nature for the benefit of the young learner.

Cropping to suit the summer vacation.—The worker in the school garden labours under a very grave disadvantage: the summer vacation comes just at the garden's most fruitful period. The ordinary cottage garden has a plentiful supply of vegetables and a lavish display of flowers in July and August, during the greater part of which period the school garden is as a rule workerless, owing to the summer holiday season. Obviously to plant and sow, so that crops will be at their best at this time of the year, is a mistaken policy. Vegetables and flowers must be grown so that part of the harvest is very early and part very late, in order that there may be no waste by the rotting of vegetables and seeding of flowering plants during the holiday months. In ordinary years this is not so very difficult of attainment if the garden-worker is content with only a few early crops, and if he judges well the time when these should be planted or sown.

The safest method of working, then, is to fix upon those crops which are to be brought to ripening point before the vacation, and to sow these early. Some crops are desirable both early and late, for example, peas, potatoes, cabbage, cauliflower, etc.; in which case part of the row, or rows, must be set to give an early crop and part a late one. The same holds with regard also to flowers.

Perhaps nothing hinders more the production of fine and abundant bloom than the development of seeds, for one seed vessel and its contents withdraw more nourishment from the plant than do many blooms, and therefore the best method of ensuring a continued show of flowers is the steady cutting of blooms. For efficient work, flowers must be chosen which will bloom in spring and early summer, or in late summer and early autumn, which after all is not so very difficult if the catalogue of a trustworthy firm be consulted and the seeds of annuals sown to suit the weather and the desired season of blooming.

4. Dates for planting and sowing.—The following list gives the approximate length of time from sowing or planting, as the case may be, to harvesting, and should help considerably in enabling the grower to judge at what date he must sow or plant, when he has once fixed the fortnight during which harvest is desired. Of course much depends upon the varieties grown, but the several kinds most suited to any particular district can be found only by experience, or from some one who has acquired the knowledge by repeated trials.

The period of vacation, during which time ordinary market-garden growers must have produce at maturity in greatest abundance, has been omitted as a harvest time in the following particulars. If it is found possible to give the necessary attention to the school garden during summer holidays, then planting should be done as advised in the calendar of garden operations at the end of this volume.

Beetroot.—An early crop of globe-shaped beet may in certain localities and with suitable weather be ready for pulling about the middle of July, just before the summer vacation, if the seed is sown in early April. May frosts, however, too often ruin the whole of this crop. Seeds of the long beetroot variety, if sown in the early days of May, produce a crop which should be harvested just before frosts come on in late autumn.

Broccoli.—Same as late cauliflower. Lay in November.

Broad beans.—Sow in early April to pull in September.

Brussels sprouts.—Sow seeds at the same time as late cabbage, *i.e.* the beginning of March, and plant out in early May to cut from late September onwards.

Cabbage.—Sow the seeds in beds thinly about July 20th, or, if the vacation begins about the middle of the month, on the last day on which the school meets. The plants are ready for setting out in September in the ground from which early potatoes have been dug, and may be cut in March. For a late crop, sow the seed in the beginning of March, plant out in early May, and cut from September onwards.

Cauliflowers.—Sow the seeds on the first school day in September (the middle of August would be even better) in a cold frame. Winter in the frame, giving plenty of air, and shielding from alternate frost and sun. Plant out in March to cut in May and June. For a late crop, sow outside in the end of March, and plant out in early June to cut in September.

Carrots.—Sow seeds about the middle of April, thin out by the end of May, and lift in September or October.

Celery.—Sow in a hot-bed about the end of February. Prick out 2½ inches apart, as soon as they can be handled, into a cold frame, the inside of which is made up of well-rotted manure, 4 inches deep, and above that a layer of good soil, 1 inch deep. Plant in trenches in the end of May.

Curly kale.—Sow seeds in March. Plant out in May to harvest from September onwards.

Early turnips.—Early Milan purple top is very suitable. Sow seed the third week in April to pull about the middle of June.

Herb seeds may be sown in the end of April or the first half of May, and are fit to be pricked out before the summer vacation.

Kidney or French beans.—Sow in the third week of May. Gather in September.

Leeks.—Sow in February, if possible, in a cold frame or outside. Plant out in May, and harvest as needed during autumn and winter.

Lettuce take longer to mature than do radishes. Seeds sown in the first week of April produce usable plants in June. For a later crop sow in the second week of July to harvest from seven to nine weeks later.

Onions.—Sow in a cold frame on the first school day in September (the early part of August is the market-gardener's time), and plant out in March. The bulbs are ripe in late July and August. If the seed is sown outside as early as February, the crop may be harvested in September, but those grown by this latter method are more susceptible to fly attacks than those grown by the former.

Parsley.—Sow in late March or early April. The seeds take from four to six weeks to germinate. These yield a supply in June and July. For winter supply the seed should be sown on the first school day in September (the middle of August is better).

Parsnips.—Sow seeds outside in February if possible. Harvest as needed throughout winter.

Potatoes.—First earlies (Midlothian early, Duke of York, May Queen, etc.), if well sprouted before planting, mature in from nine to ten weeks. If planted in April they may be dug from early June to the middle of July, according to locality. Main crop varieties (British Queen, Up-to-date, Factor, etc.) require about four months from planting to harvest. Planting in this case should be delayed until all danger of frost-nipped young tops is past.

Peas.—Sow during the New Year week if soil and weather permit, and if not, as soon as possible before the middle of February. The crop will be fit for pulling in May and June, if first earlies, May Queen, Gradus, Ameer, William First, etc., are used. For a later crop to come in after the summer vacation, a pea like Gladstone, Alderman, or Autocrat, should be sown from the middle of May to the first of June.

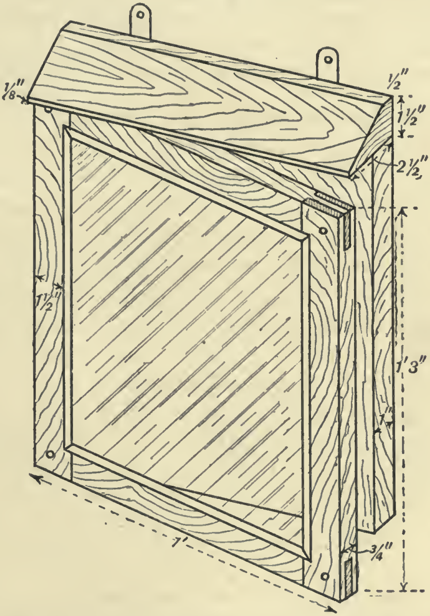


FIG. 30.—Calendar case with hinged glass front. Material—Yellow pine. A list of the main operations for each month should be written out and pinned up in the calendar case which is hung in a prominent place in the garden.

Radishes take about three weeks from sowing to harvesting. Sow about the second week of May to pull in June along with early lettuce.

Runner beans.—Sow in the first week of May, four beans to each pole. Thin out to two. Gather from September onwards.

Shallots.—Plant as soon after New Year's day as the condition of the soil and the weather will permit. The bulbs are ready about the end of July.

Spinach sown in mid April is ready for using in June.

Swedes.—Sow about the middle of May, thin out to 9 inches, and pull after they have received a good touch of frost.

5. Flowering plants.—To fit the blooming season of flowering plants to the school year is also a simple matter, all that is necessary being a little knowledge, a good seed and plant catalogue, and the faculty of doing things at their right times. The student is referred for the necessary information to the calendar of garden operations.

Differences in local weather.—No definite dates for sowing can be fixed which will be suitable for all districts, parts of County Durham being later than certain localities in the central lowlands of Scotland, and the more favourably situated districts of the Morayshire coast being a fortnight earlier than Huntly, which is some twenty miles further south, but inland. Were it possible to give exact dates for all gardening operations, half the charm and satisfaction of growing crops would be lost, for the pride of the gardener is to produce good early crops in spite of the weather and climate, rather than because of them.

Nature is usually on the side of the grower in that no matter how disadvantageous the circumstances in which a plant may be growing, it puts up a good fight for life, striving to fulfil its intended destiny in the economy of nature; but in the matter of weather, too often the gardener has to watch the moods of nature and seize an opportunity the like of which may not recur for a fortnight, if the plants are to mature when he most wants them. Even when the seeds have been safely sown and the young plantlets have forced their way above ground for some distance, a frosty April or a wet cold May will surely retard growth to such an extent that all carefully laid schemes for an early harvest come to naught.

The formation of a good seed-bed.—Each operation in gardening is done with a definite purpose, and this purpose usually is intimately related to the production of a fine plant or a good crop. The necessity of much and careful raking in the preparation of the seed-bed has been insisted upon; not that the bed may have a tidy appearance when the work is done, but that the seed may be placed under the best possible conditions. For germination alone is what is kept in view in the formation of a seed-bed—the subsequent growth of the plant is not at this time so much considered.

Requirements for germination.—Now what a seed needs, that it may sprout strongly and naturally, are a continuous supply of moisture and a suitable temperature, and unless the seed-bed is such as to afford these, the future plant begins its existence under unfavourable conditions.

Supply of moisture.—During the winter months much water has been supplied to the soil in the form of snow and rain. At the Gordon Schools from October, 1911, to April, 1912, over 3000 gallons of rain fell upon each plot of 30 feet by 9 feet. Now it is obvious that the whole of this moisture has not been retained by the soil: much has passed away as drainage water; while much has been lost by being evaporated from the surface. But a good deal has been retained in the soil, not lying in the earth as does water when poured into a jar, but held as a film of moisture round each particle of soil.

The same condition of things may be obtained by hanging a marble from a piece of thread, dipping the marble into water, and then withdrawing it. A very slight film of water will be found to cling over the surface of the marble. The smaller the particles in the soil, the larger is the area exposed for moisture to cling to, a cubic foot of marbles each 1 inch in diameter presenting but some 27 square feet of surface, while a cubic foot of spherical particles, each one thousandth part of an inch in diameter, has some 38,000 square feet of surface. Thus sandy soils, the particles of which are relatively large, are much less capable of holding moisture than is a clay soil, the particles of which are infinitely smaller.

It is evident that not the water which **lies** in the soil is the most suitable for plant use, but the water which is **suspended**, or retained round the soil-particles. The business of the soil-worker is to see that the former water is drained away; while the problem upon which he must expend much thought and energy is how to keep the latter water from escaping from his ground.

Now when the last drop has drained away from a piece of ground through the drain-pipes, a great deal of moisture still remains suspended in the soil round its particles. This cannot be lost by drainage downwards, but as though every possible agent were at work to cause the gardener to lose the moisture he so much needs, loss now proceeds upwards by evaporation. The sun, beating upon the upper layers of the soil, evaporates the moisture retained there, and this water-vapour passes into the atmosphere. But when the water in the surface layers has been exhausted, loss of water by evaporation does not cease. Moisture passes up by capillarity from the lower reaches of the soil to take the place of that which has been lost, and this in turn is evaporated, when again more moisture rises from beneath. This process continues, until by its means, the greater part of the soil-moisture is lost.

Air-spaces in the soil.—Fill a glass vessel with marbles or with lead shot. That these spheres do not occupy the whole space enclosed by the jar is evident, as a considerable amount of water may be poured into the marble- or shot-filled jar without displacing the contents. This space which the water fills represents those parts of the jar-content which these bodies cannot fill, owing to the fact that they are spherical, and thus touch each other only at certain points. Previous to the pouring in of water these spaces were occupied by air, bubbles of which may be seen escaping if the neck of the jar be narrow. The fact that these bubbles escape towards the mouth of the jar indicates that there is continuous connection between the air-spaces from the bottom of the jar to the surface of the marbles, though obviously such connection cannot be represented by a straight line.

Capillarity of the soil.—Similar conditions obtain in the case of soil, with the difference that the particles are infinitely smaller, as are also therefore the air-spaces. So minute indeed are the air-spaces that their diameter hardly exceeds that of a hair, and for this reason the soil is said to contain hair-like or capillary tubes ; these, of course, must not be supposed to be straight like glass-tubing, as connection between one air-space and another is possible only by passing round the particles.

6. Capillary action.—Dip perpendicularly into a dish of water a piece of glass-tubing with a capillary or hair-like bore, and open at both ends. Note the water-level inside the glass-tubing and also in the dish. What do you notice? Take another piece of tubing of larger bore and do similarly. Again note and record. Mark the point to which the water rises inside the capillary bore ; cut the tube slightly below this point. Again insert it in the water to the same depth as before. Encourage the water to overflow from the cut surface of the tubing, and wipe away that which overflows by means of a piece of blotting paper. Note how overflow again takes place when this water has been removed.

Condition governing free upward motion of water in the soil.—So long as the capillary pore-spaces in the soil are connected, *i.e.* so long as no large air-spaces are formed by the presence of rough lumps of earth, large stones, etc., across which, of course, it is impossible for the moisture to pass as the capillary tubes are broken, so long will soil-moisture continue to pass from the lower layers of the soil to the upper. But let the soil contain unbroken lumps of earth, large stones, large air-spaces unfilled by soil, and the ascent of moisture is broken; the surface layers become depleted of water by evaporation, and no moisture rises up to take its place.

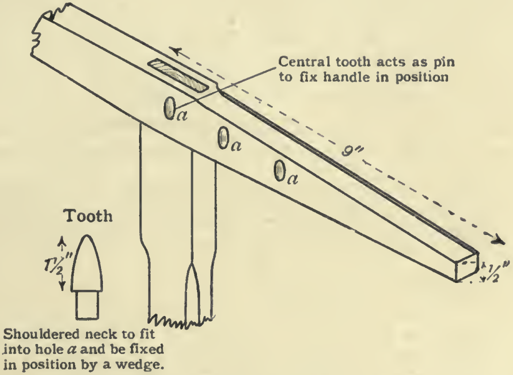

Central tooth acts as pin to fix handle in position
a
a
a
9″
Tooth
1½″
½″
Shouldered neck to fit into hole *a* and be fixed in position by a wedge.

FIG. 31.—Sketch to show construction of wooden rake. Material—Larch. Used for final levelling of the surface of the plot.

The making of a seed-bed.—In the preparation of a seed-bed, therefore, the soil must be raked and re-raked until all lumps are thoroughly broken up, all large stones removed, and the soil is worked into all the large spaces. This will result in an uninterrupted connection between the lower reaches of the soil and the upper, and will therefore ensure a free passage for moisture.

But to prevent any possibility of accident, the garden-worker goes one step further. Having sown his seed, he carefully packs the top soil by treading, or by firming the surface with the back of a spade, or the end of a rake. This causes the capillary tubes in the surface soil to become of even smaller diameter than before, owing to the pressing together of the soil-particles and the resultant lessening of the air-spaces. The soil-moisture is thus caused to rise to a higher level and ensures an abundant supply of water for the seeds which lie in the surface inch or so of soil.

Temperature necessary for germination.—The second requisite for germination is a suitable temperature. For this the gardener is dependent upon the season, but generally by sowing at a certain period he may depend upon the necessary degree of warmth. He does not sow out-of-doors when the temperature is close to freezing point, for he knows that such conditions are inimical to germination, so he waits until the season befriends him. Again, he does not sow kidney beans at the same time as parsnips, for he knows that while the seedlings of the former cannot stand frost, the latter seeds are slow in germination, and frost has little effect upon the sprouting plant.

Sowing of seeds.—The depths given at which to sow are, of course, approximate (Fig. 24). Indeed it will be found from the experimental plot, where seeds, say, of turnips, are sown in lines at depths of ½, 1, 2, 3, and 4 inches, that the seeds come up well even from the latter depth, though their appearance will be a little delayed. At harvest time, however, small difference will be evident in the crops at the different depths given.

The general advice given to a garden-worker at sowing-time is "Sow thinly," yet such is the natural propensity to guard against too thin a crop, that rarely does one meet a gardener who sows thinly enough. Seed is cheap, of course, and the extra expense is but small; but when thinning-time comes, the work is doubled or trebled by thick sowing, and plants are apt to be overcrowded. Therefore, no matter how ineffectual be the advice, it is again given: "Sow thinly."

One condition only justifies thick sowing, and that is poor seed. If a seedsman once supplies such, he should never have the opportunity of supplying any seeds whatsoever in the future. It is advisable to test the percentage of fertility of at least one kind of seed each year previous to planting, and judge from the result of this at what thickness to sow all the seeds supplied, allowing that all are equally poor or equally good. This can be done in the following manner.

7. Percentage of fertility.—Take twenty seeds of leek, parsnip, turnip, pea, etc., haphazard, without any attempt to choose the largest and best formed. A set of the season's supply should be used, and one or two kinds of last year's seeds should also be tried to note the difference in quality.

Place the seeds in each case between two layers of damped flannel, which is then laid in one saucer over which another is inverted, so that conditions with regard to light and moisture are procured as similar as possible to the natural conditions in the soil. Keep in a warm room; renew the supply of moisture as necessary; examine each day and remove each sprouted seed as it appears. Keep a record as given below. Calculate the percentage of fertility of each.

The following table shows the percentage of fertility of parsnip seed supplied the previous year, 100 seeds being taken, and shows very clearly the justice of the plan adopted by reputable seedsmen with seeds left over at the end of the season, namely, that of burning the lot.

Parsnip seed of previous year's supply. (100 seeds taken.)

Days.	No. of seeds germinated.	Days.	No. of seeds germinated.
1	0	13	0
2	0	14	0
3	0	15	0
4	0	16	0
5	0	17	1
6	0	18	1
7	0	19	2
8	0	20	4
9	0	21	4
10	0	22	0
11	0	23	0
12	0	24	0
		Total, - - -	12%

A similar experiment was performed with beet seeds of the present year's supply, in which case 81% germinated.

Weather observations.—The time has now arrived when the student, if he is to be successful in his gardening operations and is to derive full educational benefit from his weather observations, must begin to attempt to compare, contrast, and correlate these observations with a view of finding out facts concerning weather which may be of use to him in the growth of crops. He should now have a considerable number of data to work from; and while he is not yet in a position to attempt to form general conclusions, yet he should certainly be able to arrive at certain facts from observation of the readings for each month. If these facts be written down and kept during succeeding months, it is surprising how many simple rules may be formulated in the course of a couple of years.

A word of warning, however, is necessary here. No general laws can safely be laid down as a result of one year's observation. In fact, as is mentioned later, the carefully kept records of half a dozen years may be insufficient for this purpose. But a habit of observation and deduction once acquired is certain, as the years grow, to result in a knowledge of local weather lore which cannot but be useful to the student, no matter what his future business in life may be.

Explanation of construction of weather chart (Figs. 32 and 33).—The barometric readings need little remark. Note distinctly 1911 and 1912 readings. The readings are in centimetres.

The thermometric readings are given as maximum and minimum. The readings are taken each morning at 9 a.m. Thus, for example, on the morning of the 10th the maximum for the 9th is taken, as is also the minimum reached during the night of the 9th.

The rain and wind chart is intended to show the direction of the wind and the duration of the rainfall. Thus, on 29th August, 1911, the wind blew from the N.E. and was dry, so a length of a quarter of an inch was measured along the space indicating N.E., a line drawn across, the date inserted, and the space left uncoloured as there was no rain. On 29th August, 1912, again the wind was N.E., but rain fell throughout the whole day, so the whole space was coloured. On 4th August, 1912, the wind was east, and rain fell from about 9 a.m. until nightfall, so three-fourths of the space was coloured.

The amount of rainfall is recorded on a different sheet, immediately after a fall sufficiently heavy to measure. These data are added for the month and recorded in the vacant spaces as shown.

8. Examination of the weather chart.—Examine the given specimen chart (Figs. 32 and 33), which shows the weather record at the Gordon Schools for August 1911 and 1912.

For 1911 note the following: Lack of rainfall during the month was accompanied by high maximum temperature and great range of the minimum temperature. The greater proportion of the winds were south, save for two periods of four and again of three days, when they blew from the north. On each of these occasions the maximum temperature was markedly lowered, while the cold winds culminating on the 17th caused a rapid fall in the maximum temperature. South winds beginning on the 5th, and continuing until the 9th, caused a marked rise in the minimum temperature and a corresponding though not so emphatic rise in the maximum.

In 1912, rainfall during the month was very heavy, and was brought by winds from all points of the compass, but mainly by those from the N.E.; the greater number of the winds were N.E., and the month was characterised by a relatively low temperature, which persisted not only during the prevalence of N.E winds, but was evident throughout the whole month, the exceptions as a rule being those days on which no rain fell. This low maximum was accompanied by not nearly so great a range between the maximum and minimum readings as was evident in 1911, but the minimum of 1912 was almost steadily lower than that of 1911. The same connection between south winds with a rise in temperature and north winds with a fall is not nearly so marked as in the former year, doubtless on account of the fact that the prevailing wet weather influenced the temperature to a marked degree; but the N.E. winds of the 26th and 27th were accompanied by a marked fall in the maximum, though by no such difference in the minimum, the cloudy evening of the 26th doubtless accounting for this.

Attempt to connect the barometric readings with the rainfall. Note, for example, how in 1911 the fall of the barometer on the 3rd, 4th, and 5th was succeeded by rain on the evening of the 5th, and how again the fall from the 12th to the 16th culminated in rain on the latter date. In 1912, the rising barometer from the 9th to the 12th is one of the most marked features of the graph, and examination of the rain chart shows that during the evening of the 10th and the whole of the 11th and 12th no rain fell. But the sudden fall from the 12th to the 14th was accompanied by heavy rain on the 13th and 14th.

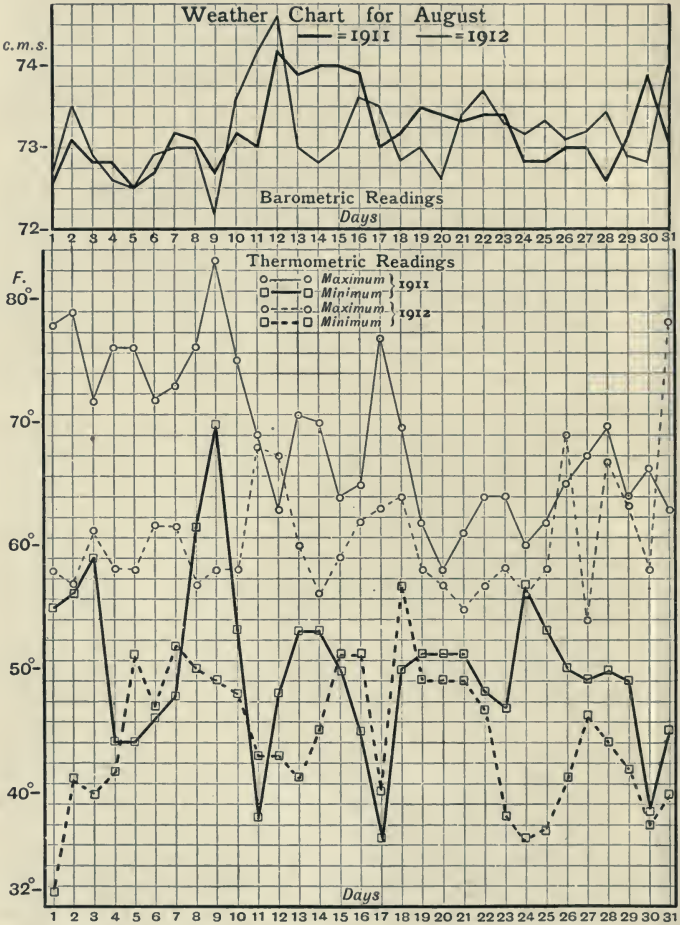


FIG. 32.—Barometer and thermometer readings at Huntly, August 1911 and 1912.

Deductions from observations.—If weather observations cease with recording, little that is either educative or of advantage to the garden-worker is accomplished. In fact, it is only by carrying out observations over a considerable number of years, and by examining these with a view of finding out possibilities of forming rules for his own guidance in the case of certain eventualities, that the garden-worker can become so acquainted with local conditions as

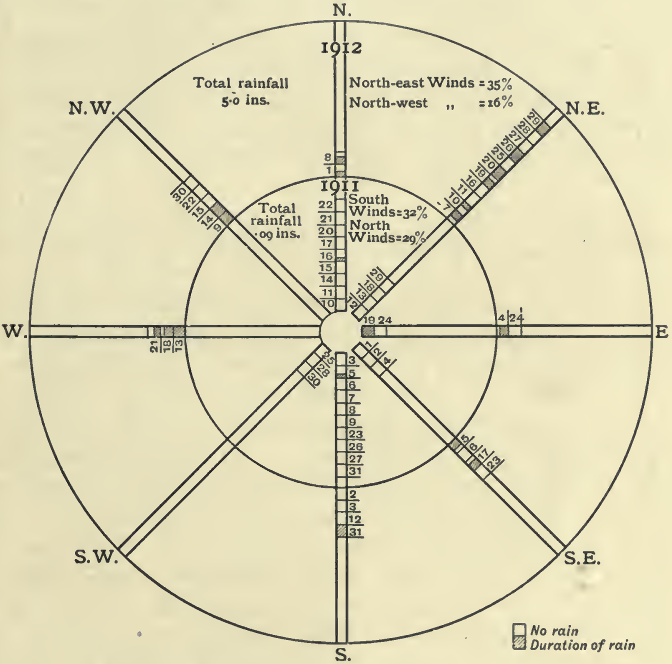


FIG. 33.—Rain and wind at Huntly, August 1911 and 1912.

to be able to form a tolerably correct opinion of the type of weather which he may expect to follow as a result of certain phenomena.

It may be recognised at once that such proficiency is not to be looked for as an immediate result of a couple of years' observation in school; but it is at least possible to lay the foundation of such knowledge, if observations are taken regularly during the later years of school life, and comparisons and contrasts noted.

The following study of the weather conditions recorded on the given chart is included merely to direct the student in his attempt to form "weather rules" for his own locality, and it must be distinctly understood that the student need not be surprised to find that the examination of the weather chart for his neighbourhood may compel him to arrive at conclusions directly opposed to those which in this case are most obvious. Indeed, in the given chart several instances will be found where it is evident that the conclusions arrived at below do not hold. These exceptions must be omitted in a first study of all weather charts, and attention given only to those cases where certain conditions are accompanied over and over again by similar phenomena.

Direction of winds.—Winds from the south, south-west, and south-east are usually warm winds, resulting in a high maximum temperature; while north, north-east, and north-west winds are cold as a rule, and when they prevail the maximum temperature is low. This is just what might be expected in summer, for a wind from a southerly direction, *i.e.* from a warmer climate, is naturally warm, except in certain cases where, for example, it passes across snowclad hills previous to reaching the district where observations are taken (Fig. 1). On the other hand, a wind from the more or less polar districts of the north must be expected to lower the temperature of the districts in the south. Thus, should a wind from a northerly direction spring up during evening, the garden-worker may expect to have to record a very low minimum temperature next morning; while if the season is spring time, and he has neglected to take the precaution of sheltering his young potatoes, roses, etc., he need scarcely grumble when he finds them black and limp, for his observations should have indicated to him what he might expect.

Night-temperature and cloudiness.—But if we examine the wind and rain chart for 1912, consulting at the same time the graph of the minimum temperature, we find that the range of the minimum temperature is very markedly influenced by a factor other than the direction of the wind. If the period from the 19th to the 26th August, 1912, be examined, the following facts will appear. On the 19th rain fell and the sky was cloudy. The minimum temperature was comparatively high. On the 20th and 21st rain again fell and the night temperature remained the same. The 22nd was fair, *i.e.* no rain and a comparatively cloudless sky, and was succeeded by a drop in the night temperature. No rain fell on the 23rd, and the drop in minimum temperature is very marked. The 24th and 25th are again rainless, with rather cloudless sky and a low night temperature. Rain fell on the 26th, and the minimum temperature of the following night was considerably higher. For this period, therefore, it holds that a cloudless night following a rainless day is accompanied by a low night temperature, while when the sky is clouded at night after a day of rain the minimum temperature is considerably higher.

More than enough harm may be done in one night, by a frost whose likelihood has not been foreseen, to counter-balance the good accomplished by a week's hard labour. An even surer method of judging the possibilities of night frost is given in the chapter on fruit trees. In fact, it is scarcely possible to take too many precautions in this connection, for a very little forethought may be the means of saving a season's crop.

It is necessary to point out here that when the minimum thermometer, which is hung four feet above ground, registers a temperature quite 4° or 5° F. above freezing-point, the leaves of young potato plants and of roses may be shrivelled with frost. These conditions are more common on a still cloudless night, when owing to much radiation the heat of the earth's surface rapidly passes away into the surrounding atmosphere. The colder and heavier air tends to sink down and lie close to the surface of the earth. Thus the temperature there is much reduced. Higher up, the air is slightly warmer and lighter, so that the reading of the minimum thermometer is but a slight indication of whether or not there was ground-frost during the night.

When the minimum temperature is lowered by a cold northerly wind, which reduces the temperature in all the lower layers of the air, there is naturally no such difference between the temperature on the ground and that four feet above it. In fact, if there be any protection round the garden, the temperature at the surface of the soil may be even higher than that recorded by the minimum thermometer four feet above the surface. The student may note this for himself when he finds tall-growing rose bushes badly shrivelled by a cold wind, while low-growing strawberries have not suffered at all.

Connection between barometric readings and weather.—One further general rule is very evident from the above chart, *i.e.* a falling barometer is usually succeeded by rain; a steady or rising barometer by fair weather. This may be explained in a word, and the explanation of so easily-understood and so common a phenomenon is given here because the writer has found students of nineteen and twenty years of age who, while grasping the facts, had but little understanding of the scientific principles underlying them.

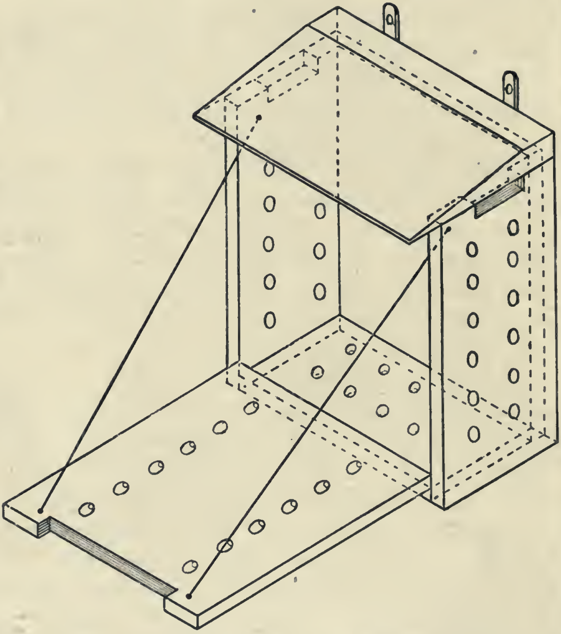


FIG 34.—Screen for two sets of thermometers. Material—Yellow pine. Inside dimensions 11″×9″×4½″. All ventilation holes save those in the bottom are bored at an angle of 45°, passing from without upwards towards the inside of the screen.

We have found that a fall of the mercury in the barometer is usually succeeded by rain. The falling of rain is an indication that the atmosphere is so saturated with moisture that it is unable to retain the whole of it, and some condenses and falls. This moisture, however, does not exist in the atmosphere as a liquid but as a vapour, in fact as invisible vapour. That this vapour is lighter than air is evident from the fact that it was originally evaporated from seas, rivers, etc., by the sun, and was buoyed up in the atmosphere. Even when part of it becomes visible and takes the form of clouds, etc., it is still lighter than the air which buoys it up.

Thus when the atmosphere becomes heavily charged with water-vapour, it is much lighter than if it were composed of dry air alone. The result is that the atmospheric pressure downwards is decreased, a shorter column of mercury is thus supported, *i.e.* the mercury falls; and the more saturated the air becomes the lighter it is, and therefore the shorter is the column of mercury upheld. So that a fall of the mercury in a barometer is an indication that the atmosphere is becoming less and less heavy on account of the fact that it is becoming more and more saturated with water-vapour. A point is reached when the fall of rain is inevitable. As a result the air becomes drier, and the mercury rises.

CORRELATED EXERCISES.

1. Clay soil is the latest in the season to be worked by the farmer. Can you account for this? What connection has this with the fact that clay land produces crops which are harvested late?

2. Account for the fact that the soil is in a suitable condition for sowing in south and east England considerably earlier than it is in north and east Scotland.

3. Why is wheat largely grown in England, while but a small proportion of the arable land of Scotland is under this crop?

4. Foreign early potatoes are in the market long before the school garden crop is ripe. Where do they come from? Account for the earliness.

5. Irish labourers who used to come to Scotland to harvest potatoes, began work in Ayrshire on the west coast and worked eastwards. This implies an earlier harvest on the west coast of central Scotland than on the east. Can you account for this? Has the geographical position of Ireland anything to do with it?

6. Why is it that all garden seeds are not sown about the same date?

7. What influence has the nearness of a district to a large body of water upon the date of sowing? Upon tendency to frost?

8. Sir John Murray has calculated that the land surface of the earth receives about 29,350 cubic miles of rain per year, and that of this only 6520 cubic miles find their way to the sea by means of rivers, etc. What happens to the remaining large proportion of over 22,000 cubic miles?

9. Account for the fact that during a period of drought, crops on sandy soils show signs of drooping long before those on loamy ground, despite the fact that each received the same amount of moisture to begin with as rain and snow.

10. How is it that, during a period of drought, trees show no signs of lack of water, while grass growing close by is brown and parched?

11. Why does the farmer roll ground in which wheat has just been sown? Why does he loosen the surface soil between rows of turnips during the growing season?

12. How is it that dark-coloured soils absorb and retain heat better than light-coloured?

13. Explain how the monsoon regions of the world are so extremely productive. What influence has this upon the density of the population? What types of plants are here cultivated?

14. Answer the following questions from examination of your weather chart when your observations have run over a period of six months or so:

(*a*) From what direction do the prevailing winds blow?

(*b*) What percentage of the winds are rain-bearing?

(*c*) Which winds are usually accompanied by rain, by snow, by cold weather, by warm weather?

(*d*) What kind of weather is to be expected when the barometer is rising or steady?

(*e*) What does a falling barometer foretell?

(*f*) When the wind veers away to the east or to the north towards evening during spring, what effect will this have upon the minimum temperature, and therefore upon your delicate sprouting plants unless you protect them?

(*g*) Do young tender plants need protection in spring during a night following on a clear, cloudless, warm day? If so, why?

CHAPTER V.

SOWING AND PLANTING.

1. Marking off the lines of crops.—Thoroughly rake and re-rake the seed-bed, one pupil working from each side across the plot, until it is free from all lumps and stones, and the plot lies level from end to end. Several rakings are necessary for this, but such work is well repaid later.

Stretch a tape-line along the 30-feet side of your plot, insert a tally or peg (Fig. 35) at the exact point at which each row is to be sown, marking the face of the peg at which each measurement is taken. Do similarly along the other 30-feet length, placing tallies as before and writing upon each the date, name, and variety of crop to be grown in the line. Re-measure to ensure correctness.

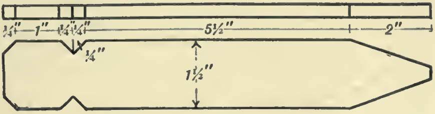


FIG. 35.—Plant label or tally.
Material—White wood or home-grown pine.

Take a straight rod of wood 9 feet long, place it from tally to tally across the plot, and press down so as to leave a distinct mark where the line of sowing is to be made.

Marking off.—Unless this part of the work is done with absolute correctness, the effect in the case of plots situated side by side is most ugly and unworkmanlike. Such work, which can result from carelessness alone, can be excused on no ground whatsoever.

Sowing and planting.—No tramping upon the soil is allowed, so pieces of board should be used to lay on the plot for standing on during sowing and planting operations. Any old pieces of wood of width sufficient to prevent them from sinking into the soil will suit. Narrow drills or furrows are made with the fingers, or with a digging stick, by working across the plot and pushing out the earth loosely to the required depth. Wider trenches, as for peas, are scraped out with a draw-hoe or made by using a spade; while potatoes and cabbages are best set in position by digging out the earth to the required depth with a trowel. The subjoined directions regarding the method to be employed in the case of each crop, if followed exactly, should result in the seeds being placed under favourable conditions for germination.

In the following notes on the different vegetables suited for growth in a school garden a number of different varieties of each is suggested. But not for a moment must it be supposed that this is intended to imply that these will succeed best in all districts. Local variations of weather, soil, and shelter may result in some variety perhaps not mentioned here doing much better than any other. The school garden presents an opportunity which should not be missed of growing as many different varieties as possible, thus experimenting to the benefit of the neighbourhood. In a garden containing (say) ten plots each with four rows of potatoes, there is no reason why (say) twenty varieties of potatoes, ten of cabbages, five of peas, and so on, should not be grown, thus giving duplicate plots to minimise the percentage of error. The crop should be carefully judged at time of harvest, and a record kept of the best and poorest yielding varieties, together with notes on any tendency to disease which may be noted.

2. **Beans (broad).** Good varieties.—Early long pod, Broad Windsor, Mazagan, Norfolk giant, Veitch's improved, Exhibition. Mazagan is smaller and hardier than the others and may be sown in November. Sow the seeds in rows, placing them 3 to 4 inches deep and 6 inches apart in the row.

Beans (French or kidney). Good varieties.—Ne plus ultra, Canadian wonder, Magnum bonum, and Negro. Sow in rows, the seeds being placed 3 to 4 inches deep and 4 inches apart.

Beans (Runner). Good varieties.—Best-of-all, Ne plus ultra, Champion scarlet. Sow in rows 4 inches deep and 9 inches apart.

Beet are of two kinds, globe-shaped and tap-rooted. Of the former, the best are Egyptian dark-red, Dell's black, and New red globe. The best tap-rooted varieties are Crimson perfection, Dell's crimson, Middleton Park favourite, and Green top. Sow the seeds in clumps, 4 or 5 "seeds" in each, the clumps being 4 inches apart. Sow clumps about of tap-rooted and globe-shaped varieties alternately in the same row. Pull the earth over the seeds with a rake, rake lightly to make level, and then consolidate the soil with the back of the spade. Use 1 ounce of seed to 100 feet of drill.

Broccoli.—Different sorts are suited for cutting in different seasons. For harvesting Sept. to Nov., Veitch's self-protecting autumn ; for Jan. to March, Queen of spring or Mammoth winter white ; for March to May, Knight's protecting ; for May to July, Methven's June. Tread the soil thoroughly until the ground is very firm. Examine the roots of the young plants, and should any nodules be evident cut them off with a sharp knife, but in any case thoroughly wash the roots in a thin mud made of water, soil, soot and lime. This holds with cabbages, Brussels sprouts and cauliflowers.

Brussels sprouts.—Good varieties are Defiance, Scrymger's giant, Exhibition and Aigburth. Treat exactly as for Broccoli, save that the earth need not be trodden and 2½ feet should be left between the plants. Apply plenty of water.

Cabbages.—For first earlies, Ellam's early (dwarf), Craigmillar, and Little queen ; for earlies, Nonpareil, Enfield market ; and for lates, Dwarf drumheads and Winningstadt are good. Of savoys, selected drumhead or Norwegian will suit. Planting should be done as in the case of Brussels sprouts, save that the distance between the plants will differ. Large growing varieties must be set 2 feet apart, while 12 to 18 inches is sufficient for those of dwarf growth like Ellam's early. Be sure your seedsman or nursery-man labels each set of plants you receive with the name, and a note as to whether they are dwarf or large-growing. Water well at planting-time.

Carrots are of two types, stump-rooted and tap-rooted. Scarlet horn, Model, and Scarlet perfection for the former, and St. Valery, James' scarlet and Long red Surrey for the latter are good. Give the soil for the row a good dressing of old soot and wood ashes. Rake this well in before sowing the seed. Mix the seeds with a little dry sand to separate them and sow in a row thinly, the seeds being set about 1 inch deep. Cover well, level, and pat the earth firmly with the back of the spade. Use 1 ounce of seed to 250-300 feet.

Cauliflower.—Good varieties are Early London, Snowball, Magnum bonum, but the names are legion, and the same variety is too often sold under different names. If the nursery-man be trustworthy, the variety, at least, may be depended upon. Plant out 2 feet apart in the rows, using a trowel in preference to a dibble (Fig. 36). Let the roots reach the bottom of the hole and be well spread out, while the base leaves of the plant should be just above the ground-line and no more. Pack the soil very tightly around the roots, leaving a slight depression in the surface soil around the plant. Fully a pint of water should be at once applied to the plant, being poured into this depression.

Celery.—Silver plume, Giant white, Standard bearer, and Major Clarke's are as good as any. Flat-bottomed trenches 18 inches wide at the bottom and 12 to 15 inches deep should have been made as early in the season as the condition of the soil would permit, the top soil being carefully retained so that it may be placed in the bottom of the trench, well mixed with mellow farmyard manure. The remainder of the soil is piled up at the sides. Plant the seedlings about 9 inches apart in a row; water well; and sprinkle the damp leaves with soot and wood ashes.

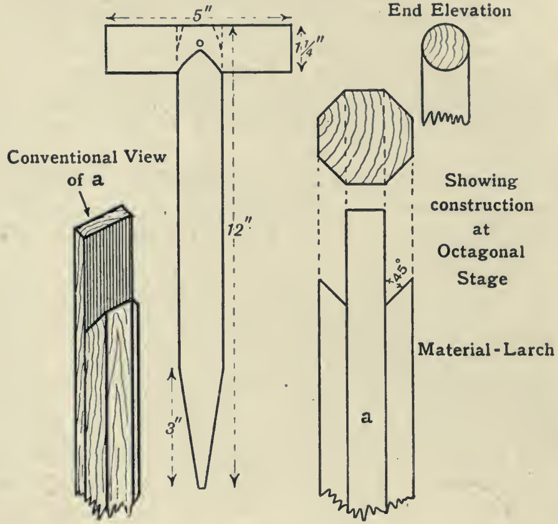


Fig. 36.—Garden dibble.

Leeks.—Musselburgh, Ayton castle giant, Prizetaker, London flag, and Lyon are all good. Sow the seeds in a continuous drill about half an inch deep, cover with soil, level, and make the earth firm with the back of the spade. Use 1 ounce of seed to 150 feet of drill.

Lettuce.—There are two varieties, Cabbage and Cos, the former being rather spherical in shape with a flattened top, while the latter is more elongated. Of the former, Giant white or All-the-year-round, and of the latter, Paris white or Hardy white are suitable. Sow the seeds in a continuous drill about half an inch deep, and treat otherwise as for leeks. Use ½ ounce of seed to 200 feet of drill.

Onions.—Ailsa Craig, James' keeping, Golden globe, Brown globe, White Spanish, A 1, and Reliance are all good. As early in spring as possible, treat the earth for onions with a good dressing of old soot and wood ash, well raked in with 4 ounces of superphosphate to the 9-foot row. One of the most important points to observe is to obtain as fine a tilth as possible for a seed-bed. This can be had only by many and careful rakings. When this has been done, tread and re-tread the soil, making it as solid as possible, and then lightly re-rake the surface until the top half inch or so of soil has been loosened. Sow the seed in a drill thinly about half an inch deep, cover, level, and re-tread or pat firmly with the back of the spade. Use 1 ounce of seed to 150 feet of drill.

Parsley.—Fern-leaved, Moss curled, Double curled, and Extra curled are good. Sow the seed in a row thickly as this is a rather uncertain crop, and the plants not only take a long time to appear above ground (4-6 weeks), but many of the seeds may not germinate. Sow about half an inch deep, and treat as for leeks.

Parsnips.—Hollow-crown, Tender-and-true, Large Guernsey, and Student are good. Sow the seeds in clumps of 4 or 5 seeds each, at intervals of 8 inches, and about half an inch deep. Cover, level, and pack the earth with the back of the spade. Use 1 ounce of seed to 200 feet of drill.

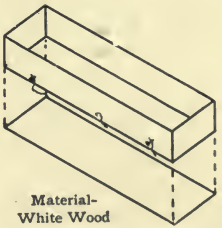


FIG. 37.—Box for forcing peas. 2′×6″×3½″. Ends of thicker wood than sides. Bottom detachable, held on by twine.

Peas.—For first earlies, Chelsea gem, William the First, Daisy, Sherwood, William Hurst, Thomas Laxton, and Gradus are perhaps as good as any, while, for a crop to come in after the summer vacation, Gladstone, Alderman, Ne plus ultra, Michaelmas, Veitch's perfection, Magnum bonum, Telegraph, and Autocrat are very suitable. Peas are classed as early and late. That does not mean that for late sowing a "late" pea should be used. What is implied is that a pea labelled "late" takes longer to arrive at bearing condition than does one labelled "early." In fact, for late sowing an early variety should be used. Peas are best sown in a flat-bottomed trench about 2 inches deep, made with a draw-hoe or with a spade, and the peas placed in the trench about 2 inches apart, not in a single row, but irregularly, as below.

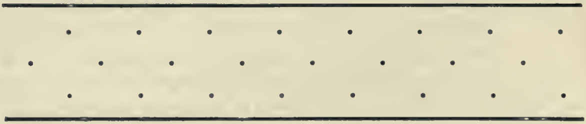


Fig. 37a.

Cover, level, and pack the surface earth tightly with the back of a spade. Very early peas may be saved from mice by being soaked for 12 hours in paraffin previous to being sown. 1 pint of peas does for a row of about 50 feet in length.

Potatoes.—As in the case of peas, the varieties are legion, and certain kinds do best in certain districts. Duke of York, May Queen, Epicure, Sharpe's victor, Early ash leaf, and Midlothian early, for an early crop; British Queen, Royal kidney, Snowdrop, and King Edward VII., for a second early; and Factor, Up-to-date, Highlander, Duchess of Cornwall, and Peacemaker, for a main crop, can generally be relied on. Of the above, Midlothian early, Royal kidney, Factor, and Up-to-date do well on heavy land; and Duke of York, British Queen, Peacemaker, and Highlander on light soil. For the early crop the "seed" tubers should be well sprouted, leaving but two buds to each tuber. For a late crop this is not necessary. Plant the tubers in rows 2 feet at least between the rows, and 1 foot between the tubers in the case of earlies, and 18 inches in the case of late sorts. The tubers should be set 4 inches deep, and are better planted by means of a trowel than with a dibble. The earth must be packed tightly around the tubers with the fingers. Care must be taken in the case of earlies that the buds are not broken off in this operation. Rake the rows lightly over and leave tidy.

Radishes.—Globe or olive-shaped varieties give better satisfaction than tap-rooted. Of the former, Scarlet turnip, Early white, and Crimson giant; and of olive-shaped, French breakfast, Early gem, and Olive-shaped scarlet are good. Sow in flat-bottomed trenches about 4 inches wide and about 1 inch deep, scattering the seed evenly and thinly over the bottom of the trench. Large seeds of radish usually yield more satisfactory results than do the smaller. Cover, level, and pat the surface soil with the back of the spade. Use 1 ounce of seed to 100 feet of drill.

Rhubarb.—Royal Albert, Early red, Early scarlet, Champagne, and

Victoria are the most commonly grown. Trench the soil well, work-in abundance of farmyard manure into the lower layers, continue alternate layers of manure and soil to within 1 foot of the surface. Set in the chosen crowns 2½ feet apart each way for the smaller growers and 3½ feet for those of stronger growth. Cover the surface with long litter.

Salsify.—Treat exactly as for leeks. Use 1 ounce of seed to 70 feet of drill.

Shallots.—Should be planted singly about 9 inches apart, in soil prepared as already advised for onions. The bulb should be about half sunk in the soil, which is tightly packed around it.

Spinach.—Long-standing and Perpetual are good. Sow as advised for beet, setting the seeds 1 inch deep. Use 1 ounce of seed to 150 feet of drill.

Turnips.—Are of two varieties, white and yellow-fleshed. Early Milan for the former and Golden ball for the latter are as good as any. To these may be added Early white stone, Snowball, Red globe, and Green round, with Swedes which come in for winter use. Sow the seeds in drills about half an inch deep, cover, level, and make the earth firm with the back of a spade. Use 1 ounce of seed to 250 feet.

When the whole plot has been laid out, make a name-plate (Fig. 38), paint your name upon it and fix it at the head of your plot.

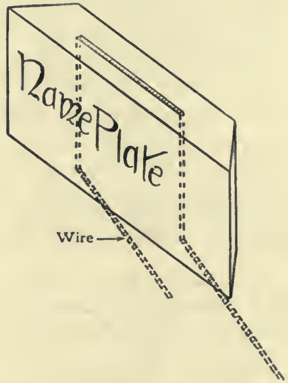


FIG. 38.—Material—White wood or home-grown pine. 7″×3½″×2″. To be placed at end of each plot.

Reasons for operations.—Unless the student in the course of his work develops the habit of asking himself, "Why is this thing done so? Why is it not done differently? Why is this and that detail so?" he must fail to benefit fully from his garden work. In fact, while he may learn to grow crops fairly well so long as conditions are favourable, unless he has acquired this observing and inquiring habit of mind he will fail miserably when he is faced by adverse circumstances in the form of bad weather, poor soil, or disease of plants. Therefore he should examine each operation of the garden, attempting to discover what natural laws necessitate different treatment in the case of different crops, what variations in growth or type of structure cause him to set some plants closer to each other than certain others, what peculiarities of seed or bulb call for a special character of seed-bed. No single operation in the garden is done in haphazard fashion; but each is the result of the application of certain laws of nature which have been studied by generations of garden-workers, the benefit of whose accumulated experience the student is reaping.

Beans bear their pods throughout the greater part of their length, therefore if plump, well-formed pods are to be had, plenty of sun and light must have free access to all parts of the plants. For this reason the seeds are sown well apart, and as a result, when the plants grow up, the stems do not run to weak length but grow strong and fibrous. The seeds of most beans are large, so large indeed that they require a large amount of moisture for germination. This moisture might not be available were they laid but half an inch deep in the soil. At the depth of 3 inches or so, however, there is no fear of such lack of water, and when the seed germinates, so strong is the build of the young plant that it easily forces its way through this depth of soil up to the surface.

3. In the experimental plot place one bean seed half an inch deep and another 3 inches down. After four days dig them up and note the difference in development. Account for this.

Beet and **Parsnip** are sown in clumps. The reason for this is that the plants must be thinned-out later to about 8 inches or so apart, and were the seeds sown in a continuous line, very many young plantlets would grow up and appropriate much of the soil-moisture and food-material, only to be pulled up and thrown away at thinning-time. This would mean much loss of food-material.

Tap-rooted and globe-shaped beet are sown in alternate clumps. The reason for this is that the latter mature much earlier than the former, and are pulled for use while the season is still young, thus leaving the soil free for the tap-rooted varieties.

Cabbage family.—The whole of these plants are especially subject to root diseases, *e.g.* finger-and-toe and gall. All signs of the latter should be cut away from the root at planting time and burnt. By washing the roots in a mud bath of soot, etc., the tendency to root diseases of this kind is decreased, for reasons which will be given later, when these diseases are discussed.

The hole for the roots of all the cabbage family, and also for potatoes, is made much better with a trowel than with a dibble. In using the latter, a deep, narrow hole is usually made, the sides of which are packed tightly. When the plant is placed in such a hole, there is usually a space around the lower roots in which there is no soil. These are thus hanging in space, are out of contact with the soil-particles, receive no moisture, and thus do not supply the plant with any food-material. The topmost roots are, indeed, in full contact with the soil, but they are confined in a narrow compass, confronted with a wall of firm soil all round, and are in competition with each other for the food-material which a small space contains. By using a trowel, the planter is enabled to spread the roots well in the hole, he can pack the soil tightly around all the roots, and thus he places them in the most suitable condition for moisture, food-material, and growth.

In the case of the potato, if the hole is made with a dibble, the tuber is seldom pushed home to the bottom of the hole, and thus its base is hanging in space, being under the same conditions with regard to soil-moisture as the lower roots of the cabbage planted in the same manner.

One member of the cabbage family, *i.e.* broccoli, develops best if the soil in which it is set be well firmed previous to planting. The plants have to withstand the rigours of winter, and, if they make much soft leafy growth in late summer and autumn, their soft tissues are especially susceptible to the attack of frost. If the plant be set in firm soil, root-development is slow, as the roots cannot quickly penetrate the consolidated ground in search of food-material. As a result, leaf development is not so free and the plant puts on strong stocky growth which renders it more capable of withstanding the winter frosts.

All the members of the cabbage family need much water. Their leafage is very extensive, therefore they transpire a very large amount of water through their stomata (p. 102), and consequently much moisture is needed at the roots to make good this loss. Besides, when the plants are set in the soil, their roots do not come immediately into quite intimate contact with the soil-particles, and so with soil-moisture. Loss of water by the leaves, however, still proceeds, and the plant may wilt and die unless sufficient water be poured in at the roots to keep these moist and cool until by the growth of root-hairs they are able to absorb soil-moisture in sufficient quantities to make up for loss by transpiration.

Carrot.—Owing to the formation of the seeds of carrot they are apt to cling together, and thus to be sown too thickly. If the seeds be rubbed among dry sand they quickly separate, enabling the garden-worker to sow them as thinly as he desires. Thin sowing is imperative. Few crops are more difficult to grow on account of the attack of the carrot-fly. This pest lays its eggs at the crown of the plant, and if the soil be loose there are no difficulties in its way when it comes to egg-laying time. Now if the seeds be sown thickly, the plants come up thickly, and the soil becomes badly loosened in the process of thinning-out the plants, so that, unless the seed be sown thinly, the grower is actually making conditions easy for one of the worst of garden pests.

Peas are sown in a broad shallow trench rather than in a narrow straight drill, because a larger number of plants can thus be had on a piece of ground, and one staking does as well for the broad patch as for the single line.

The advisability of sowing peas thinly, even two or three inches apart, is made evident by sowing a row very thickly in the experimental plot. In the case of the latter, note the dry, wilted appearance of the stems at about an inch above ground. Does this condition facilitate the passage of plant-sap? Note the general weakness of the stems, the lack of branching-out and the shortness but earliness of the harvest period of these compared with those grown 2 inches apart. The difference in size and number of pods is usually very marked also.

Potatoes should be planted with a trowel for the reason already given. The question arises here as to the advisability of cutting the tubers into sets. Doubtless where a large area is to be planted this is necessary; but in the case of small crops, as in a cottage garden for example, experiment shows that better results are to be had by planting medium-sized tubers whole. The results in the experimental plot will bear this out in all probability. However, in cases where the "seed" used are large tubers, each contains so great a quantity of starchy matters stored up, and converted into food for the growing stems previous to the time when they will be able to obtain their necessary supply by means of the roots they throw off, that a large number of buds develop rather than a few. When these begin to compete for food-materials in the surrounding soil, each receives so small a quantity that the resultant tubers are apt to be poor in size. In such a case the better plan is to cut the tubers into pieces, each containing two buds and a sufficiently large piece of tuber to provide nourishment for the growing stems until they are able to absorb food-materials and manufacture food for themselves.

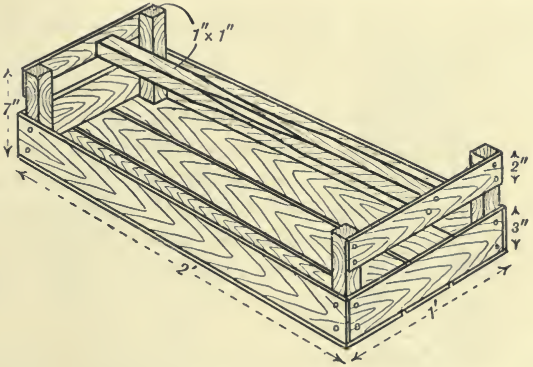


FIG. 39.—Potato tray.
Material—White wood or home-grown pine.

The whole question resolves itself into having at least two strong buds and a substantial piece of tuber with each, and if these are provided the plant is favourably conditioned for growth.

4. How to sprout potatoes.—At the time advised in the calendar of garden operations, take a potato-tray (Fig. 39) and the supply of early "seed" tubers. Write upon the tray the name of the variety it is to contain. Examine the tubers as advised in Chapter VIII., and stand them on end, base downwards in the tray. They should be laid closely together so that each helps to keep the other in position. When the tray is full, place it where it will receive plenty of light and be free from frost. A school-room window suits well, provided that the trays are removed towards evening and placed away from the window. If left in the window during the night, the buds are almost certain to be frostbitten. Note the growth of the buds. Rub off all save three or four of the strongest as soon as they have all shown signs of development. Place a tuber in the dark. Compare its bud growth with that of one set in the light. (Figs. 40 and 41.)

Radishes are sown in a broad, shallow trench, because the crop is thinned out as the plants become large enough for use. Thus the smaller plants are allowed to develop until they are sufficiently grown.

Rhubarb is a plant of rank growth and gross feeding. Therefore it requires large quantities of food-materials, which are supplied in the form of farmyard manure. In addition, owing to the large spread of leafage, it transpires a great deal of moisture. Therefore it requires much moisture around the roots, and no better means of retaining the moisture in the soil can be found than decaying farm manure and vegetable matter which act as a sponge, holding the moisture in suspension for quite a long time. Manure is dug in so deeply in this case because this plant is very deep rooted. Compare the root of the dock, which, botanically, is a near relative of the rhubarb.

Shallots and onions require a firmed soil for the same reason as broccoli, *i.e.* to prevent the roots from developing length quickly in the soil, thus absorbing much moisture which encourages much leaf growth. Shallots are set but half their depth in the soil, because, when the plant begins to split up into bulbs, the growth of these would be hindered in consolidated soil if the plant were sunk to its full depth. This is why the soil is loosened around shallots as they grow.

It is impossible for the beginner to devote too much care to the formation of a good seed-bed for the onion crop, in fact, he would be amazed did he know how much work even the professional gardener expends upon this operation ere he gets the tilth to his satisfaction. No other seed-bed needs such careful attention, and the soil must be raked, cross-raked, and re-raked until it assumes that fine mealy texture which is generally recognised as most satisfactory, but is too seldom obtained. When the soil has been well raked, it is then well trodden to firm it, but the seeds must not be sown upon this hard surface. Again the soil is raked, very lightly this time, so as to ensure that the seeds when they are sown are in full contact with the particles of the soil, and the earth is again firmed to ensure a supply of moisture by capillarity.

There must be no attempt to set all the seeds in the soil about the same time. Than this nothing is more indicative that little thought has been expended upon the work. Carefully arrange when harvest is wanted in the case of each crop; from the particulars given in the preceding chapter calculate the time taken by each from sowing time until it reaches maturity, and sow and plant accordingly.

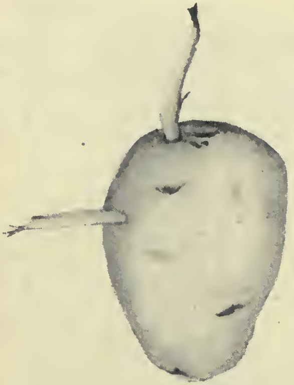


Fig. 40.—Tuber which has been sprouted in darkness.

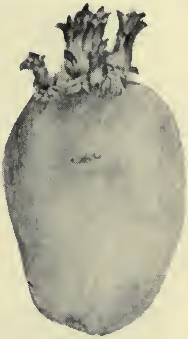


Fig. 41.—Tuber which has been sprouted in light.

5. Recognition of seeds.—Place some of the left-over seeds in test-tubes, label each, and acquire the ability to recognise them.

6. What goes on underground.—Fit up a box with a glass front as in Fig. 42. Any small box will do, the front being taken away and a piece of glass fitted into its place. The advantage of the box given in Fig. 42 is that the whole front is hinged. Fill up the box with damp sawdust or moss, slipping a sheet of blotting paper between the moss and glass. Lay the box on its back, open the hinged glass front and lay on the outside of the blotting paper a few of each of the seeds sown in the plots. Close the glass front, tie a piece of brown paper over the outside of the glass to exclude light, and leave in the schoolroom. Remove the brown paper and examine every day, noting exactly what changes occur. These conditions are very close to those under which the seeds lie in the soil, so that from the changes observed in the seeds here, you may well judge of what goes on underground during the time which elapses between the sowing of the seeds and their appearance above ground.

7. **After sowing.**—The plots must now be left wholly in the hands of Nature, save in the case when she is represented too largely by birds and slugs, in which case she must be interfered with. To keep off birds, short pegs, 9 inches long, projecting 3 inches or so above ground should be fixed along both sides of the plots, and black thread stretched across from one to the other. The birds do not see the thread on account of its colour, and striking against it in their descent upon the plot, they become afraid. If some precaution such as this be not taken, the young seedlings may suffer so badly that the whole crop may be ruined.

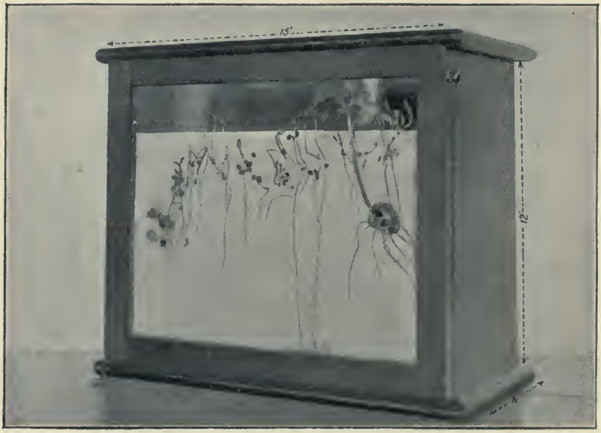


Fig. 42.—Germinating box.

Slugs should be looked for in wet weather, taken, and destroyed. A hard path and the sole of the boot provide a prompt and effective means of dispatch.

8. **Flower border in plot.**—Make a drawing to scale of the part of your plot set aside for flowers, 9 feet by 4 feet, 9 feet by 5 feet, 6 feet by

6 feet, or whatsoever dimensions you have decided upon. Now fill in the position, names, and colours of the different annuals, etc., you intend to grow here.

The flower border.—So small a space presents much more difficulty in the way of good arrangement than does a large area, and faults of design are here much more evident, as the restricted space helps to throw them into prominence. Indeed, this section of the garden betrays the good or bad taste of the worker more surely than any other part of his plot. On this account, and to ensure that each student's individuality may have an opportunity of showing itself, no specimen designs of this section of the plot are given. However, so that gross errors be obviated, a few observations of a general nature are provided.

In the first place, this part of the plot must on no account become permanent, *i.e.* it must be all rooted up and dug over in the autumn of each year, just like the vegetable part. The remains of the previous year's flowering plants, root stocks, etc., left in position are a hindrance rather than a help to the garden-worker of the year. Should he have ideas of his own which he wishes to express in design, the presence of plants already in position in all probability prevents these from being carried out. On the other hand, the lazy idea-less student derives but questionable benefit from the greater part of his design being ready to his hand. Previous to constructing his design, the student should choose the pieces of any perennials he may be able to procure which he intends to include, and work them into his design. But it should be remembered that in so small a space large clumps of perennials are quite out of place, smaller pieces being much preferable.

If the garden be large, the supply of half-hardy annuals and biennials usually available is insufficient to give each worker a large enough supply, in which case the student should rig up a small cold frame for himself either on his plot or in his home garden. One twelve inches square may easily be made to grow a supply which will fill up the space at the worker's disposal. Three or four varieties at most are preferable to a large number, if effectiveness is the point in view, and a very few seeds of each should suffice. A small form of frame which has been found extremely useful in this connection is shown in Fig. 43. If a piece of small-meshed wire netting be fixed above the glass there is little fear of breakage.

Often it is necessary to fill the bed largely with annuals, and in this case much care is necessary if results are to be at all good. In the first place, it must be remembered that the three or four short, sprouting, early-spring shoots of a perennial are but a poor indication of the spread of plant which will develop in mid-summer, and due allowance must be made for this growth when annuals are being sown. Again, broad-cast sowing will result in an interior mass of stunted plants and an outer circle of well-grown specimens, than which few sights are more unpleasant in a garden. So that annuals should be sown in straight lines or in circles, or if sown broad-cast should be thoroughly thinned-out as early as possible.

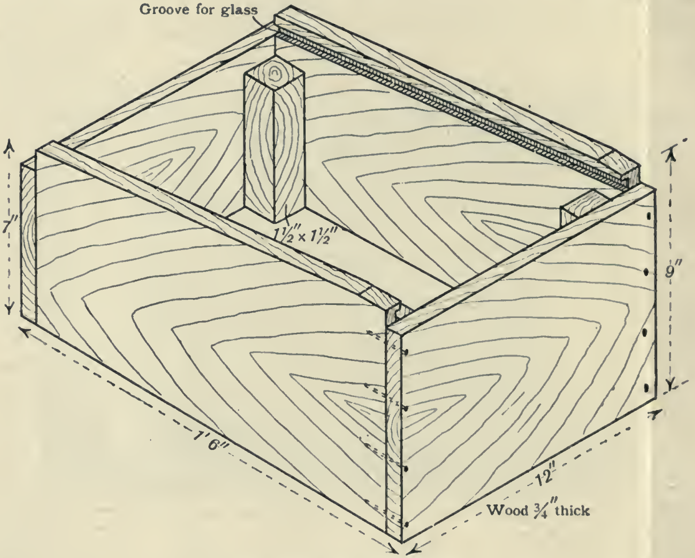


FIG. 43.—Small garden frame.
Material—White wood or home-grown pine.

Choice of flowering plants.—But even more important is the choice of flowers to be grown. It need scarcely be said that dwarf-growing sorts should occupy the front, and unless these be sown far enough back they are apt to sprawl in too often an unlovely confusion half-way across the path. With certain plants this is an attraction rather than otherwise, but it depends wholly upon the method of growth. *Calandrinia speciosa*, for example, throws out long runner-like shoots, which are certain to be trodden under foot if they encroach upon the path, while *Leptosiphon* and *Nemophila insignis* burst across the border in bushy tufts which help to give a certain attractive wildness to the path.

Naturally the growth should increase in height from the front to the back, or if it be so desired to the centre of the plot, and while there should be absolutely no signs of overcrowding—thinning-out being done until this is impossible—yet no portion of ground should remain absolutely bare. A few clumps of annuals are sufficient, the remainder of the space being taken up with perennials, biennials, and half-hardy annuals. This will result in there being a continuity of bloom, for many annuals are prone to flower together for a period and then set in seed. In fact, in choosing plants and seeds the garden-worker should consult a good seedsman's catalogue, and make up a selection which will give him a show of blossoms from as early as possible right on until the frosts come.

In drawing up a design for such a space all tendencies to elaborateness should be sternly repressed and simplicity made the ideal. Straight lines, simple curves, effectively placed clumps, are the essentials. Indeed, an elaborate design which looks very attractive on paper will usually be altogether obliterated long before the plants attain their full size, and the whole flower-border will become a formless mass of foliage and blossom.

Sowing of annuals.—The seeds of most annuals are very minute, germinate therefore with a small amount of moisture, have little strength to push their way up through any great depth of soil, and as a result should be sown shallow, from one-eighth to a quarter of an inch being sufficient. Quite a large number will fail to come up from the depth of half an inch if sown in ordinary soil. They may be sown deeper, however, if drought is to be feared, by covering them with riddled soil or compost, which does not present such great obstacles in the way of stones, etc., to the growing stem before it appears above ground.

CORRELATED EXERCISES.

1. Account for the fact that the type of wheat grown in the United States, America, is different from that grown in England, while in India several hundreds of different types of rice are found, for the most part each in its own special district.

2. Explain why the garden-worker who has to deal with a piece of ground where weeds have been allowed to seed, buries the surface 3 or 4 inches of soil so that it lies close to the subsoil. Why do these seeds not grow up into weeds in the following season?

3. Why is it necessary in our climate to sprout "seed" potatoes for a very early crop?

4. What special qualities in plants have resulted in their being cultivated by man? Attempt to find what proportion of the many families of plants in Britain have had some of their members selected by man for this purpose.

5. How can you explain that, despite the fact that many seeds of cultivated plants must be scattered by different means outside the garden, yet we but very seldom find these plants in a wild condition? Sow a little seed of each by the roadside and note what happens.

6. The original home of the potato was in all probability Chile. It had become common in New Granada before the discovery of America. In the latter half of the sixteenth century it was introduced into Virginia and North Carolina, and was grown in West Europe about the end of the sixteenth century. Examine the type of the climate experienced in each of these districts. How can you account for the growth of a plant originally requiring the climatic conditions of Chile being possible in West Europe?

7. Beans weigh about eleven to the ounce. What weight should be required for twenty plots each 9 feet wide, the seeds being placed 6 inches apart in the rows?

8. What treatment would you give to a cabbage plant the leaves of which have become wilted?

9. What type of growth is an indication that the plant requires copious supplies of water? Explain why this is necessary.

10. What type of growth is an indication that the plant requires a firm soil-bed to grow in, if it is to develop rightly? Explain the cause of this.

CHAPTER VI.

EXAMINATION OF THE GROWING PLANT.

1. Records of growth.—Construct a table similar to that given below, and fill up particulars as growth proceeds.

Plant.	Date of sowing, or planting.	Date of appearance above ground.	Points of interest, with dates.

2. Changes during germination.—Place some bean seeds in soaked flannel; leave for a day or two, and note how the parts extend until the outside skin is burst. Is the swelling uniform all over, or has one part extended more than the rest of the seed?

Take a dozen or so of the soaked beans and place them in a wide-necked bottle; dip a lighted match, or taper, into the bottle to prove that the air it contains supports combustion, and then cork tightly. Place the bottle in a warm temperature for 24 hours or so; uncork, and introduce a lighted taper. Does the taper continue to burn? Pour into the bottle some clear lime water and shake. What change do you notice?

Breathe through a piece of glass tubing into a beaker containing some lime water. What change do you notice in the colour of the water?

What is a seed?—The bean has been chosen as an example, because it is one of the largest and most easily examined of all the seeds we have sown, and is typical of most. The fact that when the seed is soaked in water extension is not uniform, one part swelling more than the rest, leads to the suspicion that we have more than mere dead matter to deal with. This suspicion grows into a belief when we find that the soaked seed has an effect upon the atmosphere identical to that produced by the breathing of living animals; at least the gas which is given off by it is similar to that breathed out by animals. The air is composed chiefly of oxygen very much diluted with nitrogen. Animals breathe this air into their lungs, where the oxygen is partly used up, and the gas which is breathed out contains a large proportion of carbon dioxide, which has the characteristic that it turns lime water "milky." We have already found by experiment that the gas given off by the soaked seeds turned clear lime water milky, and so we conclude that this gas is carbon dioxide.

The fact that it is alive is not at all apparent in the case of the dried seed, but we must remember that buds, for example, which are to all appearance lifeless in winter, are but undergoing a process of rest, and in spring will burst and bear leaves and flowers. So we may come to the conclusion that the dry seed contains a living organism which is merely dormant for a time, and under the influence of moisture, air, and a suitable temperature, it gradually assumes activity, extends or grows, and in this stage of the process at any rate uses up the oxygen of the atmosphere and evolves carbon dioxide.

3. Examination of the seed of the bean.—The dry bean is too hard for an examination to yield much of interest to garden-workers, save the outside markings, and these are of little importance for our purpose. The dark line along part of the edge indicates the place at which the seed was joined to the pod and should be noted. Beans which have been soaked in water for 24 hours are softer, and can easily be taken to pieces. Note any difference in size, form, and colour due to soaking.

Previous to being torn up, the outside should be dried with a handkerchief, and if now it is pressed between the fingers, water will be found to exude from a little puncture in the skin on the edge of the seed.

With a knife remove the outer skin. Make drawings showing a side and an edge elevation of the seed without its coat.

Carefully attempt to separate the seed along the line of parting which runs round the edge. Make a drawing of the parts as they now present themselves. Can you distinguish three? Are any two of these similar? Make a detailed drawing of the smallest.

Examine some of the beans which have been kept in soaked flannel. Which of these three parts has become most extended? Does this extension or growth take place uniformly all over this part, or does one piece of it grow more than another? Make drawings of a bean which has been soaked for 1, 2, 3, 4, 5, 6, and 7 days. Note at what date growth begins in each region.

Do the two other parts show any signs of growth once the first swelling has taken place?

Examination of the seed of the bean.—The bean seed, broadly speaking, consists of four distinct parts—an outside coat, two plump layers of whitish matter (seed-leaves), and an elongated small body, part of which is hidden between the seed-leaves, and part curved for some way alongside the edge where the seed-leaves meet. This latter body is the young plant or **embryo.**

These parts are difficult to distinguish in the unsoaked bean on account of its dry hardness. On being placed in water for a little time, the seed absorbs moisture and increases in size. That this increase is due to the absorption of water may be shown by placing some seeds in a measured quantity of water for some time, say 24 hours, and then removing them, when the level of the water in the jar will be found to be considerably lower. The moisture enters the seed partly by being absorbed through the seed-coat, but largely through the small puncture already noticed on the edge of the seed-covering.

Now it will be noticed in the case of beans which have been soaking for several days, that the seed-coat has burst, largely on account of the fact that the embryo has increased greatly in size and is forcing its way out. This it does by means of its pointed end, and, when the beans placed in the germinating box are examined, it will be noticed that this part invariably seeks earthward, no matter in what position the seed may be placed. There is no necessity for digging up the bean seeds already sown in the garden plots; these were placed there that they may bear a crop. Those placed in damp sawdust are under practically similar conditions and answer the purpose quite as well. The part which grows downwards is the **root** of the plant, and the young **stem** will be seen later forcing its way upwards towards the light.

The seed-leaves.—But the purpose of the **seed-leaves** we have not yet examined, nor can we be certain about it until the plant has grown considerably. As the root penetrates downwards and the stem grows upwards, it will be found that the seed-leaves gradually lose their fleshy appearance, grow thinner and thinner, until at last they shrivel away. Now we know that growth takes place only as a result of feeding. Young life needs something to feed upon, and as a rule is not capable of making use of the same food as it will when it is older. The little lamb for some considerable time is dependent for life upon the mother sheep's supply of milk ; the very young child does not feed upon the same food as the grown man ; and we can hardly expect the very young seedling plant not to be subject to the same law. As a matter of fact it is, and the seed-leaves are just nature's provision for the very young plant previous to the time when it can forage for itself.

These seed-leaves are really what their name implies, namely, *leaves*, and they are packed with food for the young plant immediately it begins to grow and needs sustenance.

This food is quite different from the material which the roots of the plant absorb from the soil ; in fact the latter is **raw food-material** from which food may be made, while the former is **manufactured food** ready for use. This food passes by absorption from the seed-leaves into the cells of the young plant, and a great deal of the water absorbed by the seed is used for the purpose of dissolving this food, for only substances which are in solution can pass from cell to cell of the plant. This food is gradually used up, and before the supply is finished the young plant has reached the stage when it is able to make use of the food-materials in the soil, and is able to sustain life by its own powers.

4. **Starch stored in seed.**—Place a drop of much diluted iodine solution upon a piece of common starch. To what colour does it change the starch after a few moments?

Loosen a few grains on the broken surface of a bean by scraping it with a knife. Place a drop of the iodine solution upon these. Is there any similarity in the change of colour? What does this suggest to you regarding the composition of the starch and the bean grains?

Naturally the question suggests itself, "What is the main constituent of this food which is stored up by the parent plant so that its offspring may live under suitable conditions in its early stage?" The above experiment shows very clearly that, as blue is the colour produced when iodine is applied to starch, and as this is the colour to which the seed-leaves of the bean turn when treated with iodine, therefore the bean probably contains starch. This food it is which sustains the life of the young plant in its very early stage.

If the cut surface of a potato tuber be treated in the same manner, it will be found that it also contains starch upon which the young stem feeds until it can absorb food-materials and can manufacture food for itself. This point, that starchy matter is the chief constituent of the food of plants, must be emphasised. The plant does not obtain food from the soil. It absorbs *raw food-material* from the soil, an action which may be compared to the buying-in of raw food-materials by a cook. This raw material is by and by changed into food, by a process in the plant much more marvellous than that in the kitchen, and not until the raw material has been converted into starchy matters by the plant can it be described as food. It is then ready for the use of the plant.

5. Examination of the growing seedling.—Note each day the changes which take place in the seedlings grown in the germinating box. Make drawings of the different method adopted by each seedling to push its stem above ground. This is a most interesting study, and will repay as much attention as you can give to it.

As the plantlets appear above ground in the plots, make a drawing in each case of the first pair of leaves, and later of the second pair, noting any differences which may be evident. Accustom yourself to recognise seedlings by the examination of their first leaves. Distinguish between the seedlings of weeds and the seedlings of the crops grown.

Examine the roots of seedlings which are growing in the germinating box. Does each plant send down one straight root which forces its way downwards, are any side roots thrown off from the main root, or is there no evident main root, but a bunch of finer fibrous ones? Note in each case the type.

Can you distinguish a kind of hairy down on any of the roots? Note the position of these hair-like growths. Do they appear at the point of the root, about the middle, or where? What do you suppose their purpose is?

Roots.—Some plants develop a strong main root which penetrates straight downwards, and from which **lateral** or side **roots** are given off. Others adopt a different method, sending out a host of **fibrous roots** which lie in the surface layers of the soil. It is very important to find out from experience which garden plants are deep-rooting, and which are shallow. As in most other points in gardening, personal observation is the best means of obtaining information which shall be not only lasting but, in virtue of the method adopted to obtain it, really educative.

6. **Rooting of plants.**—For the reason just given a list is not included. Make out a list, dividing the crops grown in the garden plot into "deep-rooted" and "shallow-rooted." This cannot be filled in wholly at once, but facts should be entered as the information is obtained.

These main and lateral roots are of use to the plant in two ways: they fix it firmly in the soil, and as they grow older and put on bark they act as canals which transfer dissolved raw food-material from the younger parts of the root upwards to the stem and leaves. They do not themselves, save in their very early stages, act as collectors of dissolved food-material: indeed this period very quickly passes, and the function is passed on to the younger growing portion of the root, which now comes under our observation.

Root-hairs have already been noted, and it has been observed that they appear on roots only at a little distance behind the growing point (Fig. 44). The point itself bears none, and as the root elongates, the root-hairs on the older part are continually shrivelling and new ones appearing towards the root-point part. Thus, as the root itself increases in length, the region of the root-hairs is being continually pushed forward as new hairs grow and old ones decay, while the older part of the root in many cases develops a corky covering and no longer takes any share in the absorption of moisture. In fact, it has been calculated that root-hairs remain active on an average only for four or five days, when they gradually shrivel away, their function of absorption being performed by fresh root-hairs which develop nearer the point of the root.

Structure of root-hairs.—Root-hairs are almost invisible in the case of most plants dug out of the soil, for their structure is so delicate and they themselves are so very minute, that by the very operation of disturbing the soil they are torn from the parent root; and very rarely are root-hairs seen upon an old plant which has been unearthed. But if a seedling of a week's growth be removed very carefully from the soil, root-hairs may be seen with the naked eye, while those roots which grow downwards against the glass front of the germinating box usually show them very markedly, if the box be supplied with just the correct amount of moisture. Though so very minute, these root-hairs must be considered as among the most important organs possessed by the plant, for they are collectors of the raw food-material without which the plant cannot thrive.

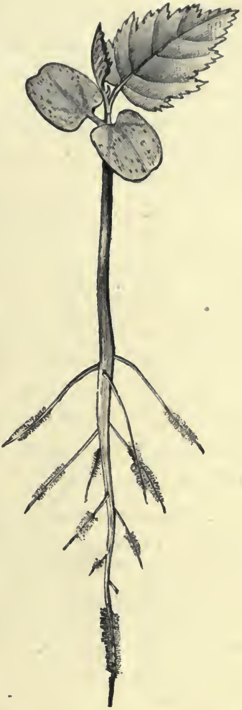


FIG. 44.—Young plant showing position of root-hairs on root.

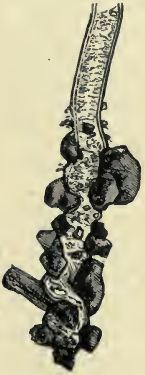


FIG. 45.—Root-hair (magnified). Note the close connection between soil-particles and root-hair.

Each root-hair, if viewed under a microscope, is seen to consist of the elongation of one single cell of the outer layer of the root, to be surrounded by a single extremely thin membranous wall, and to possess no openings of any kind whatever. Though so very minute, root-hairs are often found several millimetres in length, and they grow so thickly upon the part of the root which bears them as to result in almost every particle of soil in their vicinity being brought into close contact with the root. The close connection which exists between the root-hair and the particles of soil is well shown by Fig. 45. When the multitude of roots which any ordinary fibrous-rooted plant bears is borne in mind, and when each of these is conceived as sending out a host of secondary roots which in their turn give rise to many rootlets, each of which is provided with hundreds of root-hairs, it will easily be realised that, in the whole region occupied by the roots of the plant, practically every single cubic inch of soil is penetrated by these root-hairs, which thus come in contact with practically every particle of soil in the region.

We have already learned that the moisture which is of importance to the plant is that which is held in suspension round each particle of soil, so that the obvious conclusion is that the root-hairs of a strongly growing plant are exactly placed so as to come in contact with this moisture. It will be sufficient at this stage to state that the raw food-materials which must be collected by the plant exist in solution in this soil-water which is held around the particles, so that the root-hairs are thus in full contact with this material. The point to discuss now is, how do the root-hairs collect this material for the use of the plant?

7. **The entrance of moisture into the root-hairs.**—Get a pig's or a sheep's bladder; clean thoroughly; pour in a strong solution of sugar, tie up tightly, attach a weight to cause it to sink, and place in a vessel of pure water. Leave for 24 hours or more, and examine. What change do you notice in the size of the bladder? What change in the tightness of the outer skin? Since air could not have passed into the bladder to account for the increase in size, what must have found entrance? As no opening was left, how must entrance have been obtained? Taste the water in the pail. What do you find?

The passage of moisture through root hairs.—In the above experiment it is found that, in the case of a strong solution wholly enclosed by a membrane which is then placed in contact with water, the tendency is for the latter, *i.e.* the weaker solution, to pass through the membrane, for the bladder increased considerably in size. At the same time a flow of the concentrated solution takes place through the membranous covering outwards, for the water in the pail tastes sweet. If it were possible to allow the experiment to stand long enough, the solutions inside and outside the bladder would gradually change in intensity, until the water on either side of the bladder wall is equally concentrated, *i.e.* contains the same percentage of sugar per unit of water.

We have already seen that the cell-wall of the root-hair is membranous and without aperture, in which points it closely resembles the bladder used. Dissolved in the cell-sap of all plants are substances in solution, therefore the sap of each root-hair may well be compared to the concentrated solution of sugar inside the bladder. When the cell-wall of the root-hair comes in contact with the soil-moisture clinging to the soil-particles, by the same law which governs the passage of water through the bladder-wall, soil-water will pass through the wall of the root-hair and thus enter the living plant. This is called the law of **osmosis.**

This water which has been absorbed by the root-hair is not pure; that is, owing to the very fact that it has passed through the soil it must have come in contact with certain substances which are soluble in water, so that this soil-water which has passed into the plant contains (say) a proportion of one certain substance. If this substance-containing water remain in the cell of the root-hair, the strength of the solution inside and outside the cell-wall will be similar, so that no more of this substance will pass through the cell-wall in solution; for we have found that interchange ceases when the solutions outside and inside are in equilibrium. But, on the other hand, if this substance happens to be the raw material which the plant requires for the formation of food, it will be removed (still in solution), pass up the stem of the plant, and so reach the leaves. In this case equilibrium outside and inside the cell-wall of the root-hair is upset, and a passage of soil-water containing this

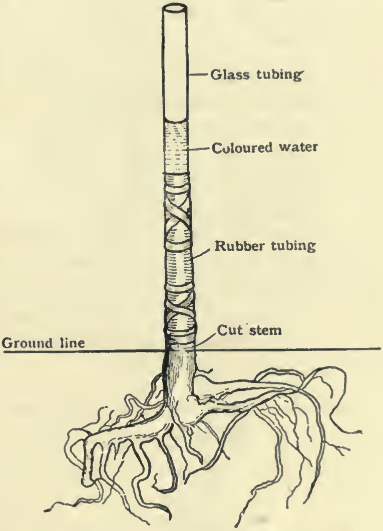


FIG. 46.—To show pressure of ascending moisture.

same substance in solution again occurs from the soil into the root-hairs. It is in turn removed upwards in the plant, and a continuous flow of moisture containing this substance in solution will go on between the soil and the root-hair.

These substances which the root-hairs absorb are the very elements from which the plant manufactures food, and they pass through the root-hairs, not in a solid form, for the cell-wall refuses entrance to all solid matter, but in solution. In this same form, *i.e.* in solution, the raw food-materials pass by absorption from cell to cell of the plant until they reach the leaves.

8. **Pressure of ascending moisture.**—Cut the growing stem of a vigorous plant—monkshood, perennial poppy, etc.—about 2 inches above the ground line, and connect with the stem-stump, by means of rubber tubing, a long piece of glass tubing containing a little water coloured with eosin or red ink. Firmly fix the rubber tubing over both stem and glass by tying with bast (Fig. 46); support with a stake; pour on to the plant a couple of pailfuls of water, and leave for half an hour or so, when the level of the coloured liquid will be fixed. Mark this point by means of gummed paper and leave the whole for 24 hours. If everything has been done exactly, it should be found that the level of the liquid has risen considerably.

Ascent of moisture in the plant.—When the growing stem is cut in Expt. 8, if the cut surface is dried with the finger, the pumping out of beads of moisture by a certain circular part of the stem may be noticed with the naked eye. This moisture is the soil-water with certain substances in solution, which is absorbed by the root-hairs and passed upwards from cell to cell of the root until it reaches the stem. The experiment proves that the plant possesses the function of forcing this sap upwards in the stem, and if the glass tubing is long enough and the temperature high enough, by continually supplying the roots with water it can be shown that the water in the glass tubing rises at least to the level of the highest point to which the cut-away part of the plant extended, *i.e.* to the leaves.

9. **The path of the ascending moisture.**—Choose a healthy small branch of a tree,—sycamore or plane will suit,—and peel off a ring of the outside bark until the woody part of the stem is exposed (Fig. 47). Examine the branch day by day. Can you detect any dying off of the

leaves above or below the ringed part? Have you cut off the plant's supply of moisture by removing the bark? Then in which part, the bark or the woody tissue, must the sap ascend?

The fact that there is no withering of the leaves above the ringed part leads at once to the conclusion that the path of the ascending moisture has not been broken by the ringing of the bark. In other words, the moisture does not rise in the bark of the plant, but in the woody tissue which is enclosed by the bark.

10. The fate of the ascending moisture.—Introduce a well developed leaf of a healthy bean plant into a test-tube, without severing its connection with the plant. Plug the mouth of the test-tube with cotton wool (Fig. 48). Support with a stake. Examine after 24 hours. What has collected in the tube? Taste this liquid. Does it appear from the taste to contain anything in solution? Varnish the under side of another leaf, or cover it with vaseline. Treat it as advised above. What difference do you note in the amount of liquid collected? Evaporate some of the liquid collected. Does it contain anything in solution?

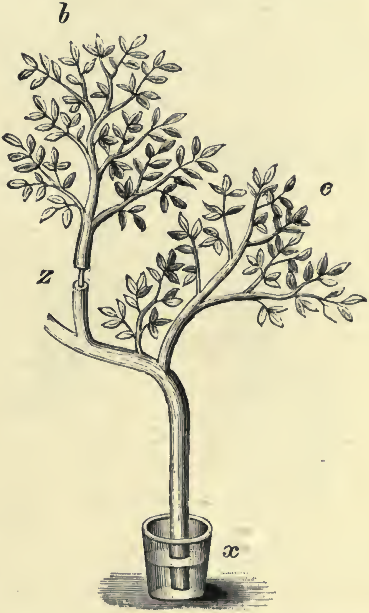


FIG. 47.—Hales's experiment to show the ascent of the sap in the wood. Although the bark has been entirely removed at *z*, and the wood alone left, the leaves of the branch *b* remain as fresh as those on the uninjured branch *c*.

Expt. 10 shows that the moisture which has been absorbed from the soil through the walls of the root-hairs into the plant, and has passed upwards through the woody tissue of the stem, is given off eventually to the atmosphere by the leaves as vapour. But this liquid which the leaves exude, or **transpire**, to use the more correct term, is essentially different from that which first passed through the walls of the root-hairs. This latter, it will be remembered, contained raw food-material in solution. The former, on the other hand, is pure water. The raw food-material, then, has been retained by the plant for its own use, while the moisture passes off by **transpiration** into the atmosphere. Examine the derivation of this word "transpiration," and you will see how well it expresses the action described.

Transpiration.—The different changes which go on in the plant are usually the result of complex conditions which it is extremely difficult to understand fully, and the function of transpiration is no exception to the rule. This loss of water is not merely the result of such evaporation as is commonly associated with the drying of wet clothes hung on a washing line, though conditions which favour rapid evaporation usually result in increased transpiration. But the action itself is largely under the control of the plant, as it proceeds through **stomata**, or air-pores, located for the most part on the under surface of the leaf, as will be deduced from the result of varnishing this side of the bean leaf. These stomata are so minute that they can be seen only by means of a microscope, and thousands may exist on the under surface of an ordinary leaf. Through these stomata water is transpired, and when it is remembered that a crop of cabbages transpires from 600 to 800 gallons of water per acre per day, all of which is drawn from the soil by the root-hairs, an idea is obtained of the enormous demands for moisture made by plants upon the soil.

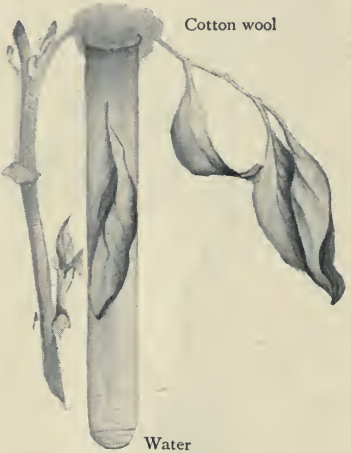


FIG. 48.—Transpiration in the case of a leaf of a broad bean.

Certainly all plants are by no means so exacting in their requirements of moisture, but even the least exacting must have several hundred gallons per acre per day if they are to be healthy and flourish. And, as in ordinary evaporation, as the water is transpired the raw food-materials are left behind in the leaves of plants, thus ensuring a steady in-flow of material for the manufacture of plant-food.

It has been stated that transpiration takes place through the leaves and that the raw food-material is left behind there. Now, this implies that the main flow of sap in the plant is from the roots upwards to the leaves, and such is the case. Naturally sap moves mainly towards that point at which it finds freest outlet, and the exterior of the plant is so constructed that transpiration takes place with greatest intensity in the leafage. This is accomplished by the development of an almost impervious corky layer of bark upon roots, stem, branches, and twigs of many plants, through which the passage of water is so slight that it may be disregarded.

11. Food in the leaf.—Take a thin-skinned leaf, *e.g.* dandelion or young lettuce, which has been exposed to bright sunlight on a plant for the greater part of a sunny day, dip it for a few minutes into boiling water, and then immerse it in methylated spirits, corking the test-tube which holds it. Leave for a few hours. Note any change of colour in the liquid and any change of colour in the leaf.

Now place the leaf in a white porcelain dish and pour some dilute iodine solution over it. Leave it for some time, and then dip the leaf into cold water to wash off any iodine which may be clinging to it. What change of colour do you now observe in the leaf? From a former experiment with iodine, what conclusion do you arrive at regarding the composition of the leaf?

Pull a leaf from the same bush just at daybreak, or from a growing plant which has been kept in the dark for a time, and treat similarly. Do you arrive at the same conclusion as in the above case?

The food of plants.—In Expt. 11 the green colouring matter which the leaf contains is first extracted by the use of methylated spirits, because with the green matter, or **chlorophyll,** we do not wish at present to deal. When this has been withdrawn the leaf is almost colourless, and when tested with iodine turns blue, a sign, as has already been shown, that starch is present. Now, this is the very substance which we found was contained in the seed-leaves of the bean, in the potato tuber, etc., and spoke of as the food of plants. So that we have reached the stage when we can say that **food-materials** are conveyed to the leaves in the plant-sap, and are left behind there as the water transpires; and also in the leaves by some process **food** is manufactured, and this food consists largely of starchy matters.

12. Starch a complex substance.—Take a few pieces of ordinary starch, a piece of wood, *i.e.* part of a plant, and a few grains of wheat which have been ground; place them in turn in an iron shovel or spoon and hold them over a hot fire, or bunsen flame. Note what happens. What colour is the remaining substance in each case? This substance is called *carbon.*

Elements and compounds.—In chemistry certain substances are called *simple*, because they are composed of single elements, which implies that no matter to what tests they may be subjected, they do not yield any second element. Others are called *complex* substances; that is, they have been built up of two or more elements, and when treated in certain ways they yield up each of these elements in turn. Expt. 12 proves that plant-food is a complex substance, for when treated with iodine the material shows that starch is included in its composition, while burning makes evident the fact that it contains carbon, and some part has certainly passed away as gas. Now we have got one step further. Plant-food is a complex substance which is starchy in nature, and, for the building up of this starchy material, carbon has been employed.

Source of plant-carbon.—The question arises, "Where does the plant obtain this carbon which goes to the formation of its food?" This is a subject which for a long time gave much trouble, and still is very difficult to demonstrate by a simple experiment. But if plants be grown in pure sand which contains no trace of carbon, or in water-cultures similarly lacking this element, they are found to increase in length and flourish, which means that they must be forming starchy material as food, and are therefore receiving the necessary supply of carbon in some form. This shows that they do not extract carbon from the soil. Indeed, it has been proved conclusively that practically the sole source of carbon for the plant is that gas of the atmosphere called carbon dioxide, a gas which cannot be called a simple element, for, as the name shows, it is composed of one part carbon and two parts oxygen.

This gas is taken in by the leaves through their stomata already spoken of.

13. Building up of starchy matters.—Place some shoots of mare's tail, or mint, in a beaker of water, cover over with a funnel, as shown in Fig. 49, and over the end of the funnel place a test-tube which is full of water. Expose to bright sunlight for some hours. What do you notice rising from the leaves of the plant?

After a few hours, place the thumb over the mouth of the test-tube while it is still below water, remove the tube, and, keeping the thumb over the end all the time, turn it up. Then remove the thumb, and plunge a smouldering match or smouldering piece of wood into the gas. Describe what happens.

It is well known that the use of a bellows, or stirring up with a poker, causes a fire to burn more brightly. This is due to the fact that a greater supply of oxygen is passing among the coals, and oxygen is an excellent supporter of combustion. When a smouldering match is plunged into the gas which is given off by green leaves in sunlight, the match bursts into flame. This suggests that the gas collected is oxygen.

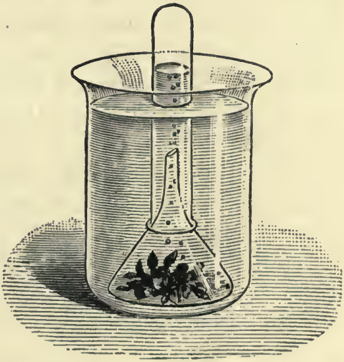


FIG. 49.—To show that leaves of plants give off oxygen in sunlight.

We have seen that the leaf takes in carbon dioxide through its stomata, and we have just found that oxygen is given off, which implies that carbon is left behind in the leaf. As a matter of fact, in the presence of sunlight the carbon dioxide combines with some of the water in the leaf; and by a chemical change, from these two substances, carbon dioxide and water, influenced by the substances obtained from the soil in solution with soil-water, sugar, or starch, and oxygen are formed. The oxygen passes off into the atmosphere, while the sugar or starch remains behind, substances ready for the plant's use as food.

If the experiment in which a leaf was tested for starch be recalled, it will be found that the leaf, which was pulled at daybreak, showed no sign, or very little sign, of starch; which means that while starch is manufactured by the plant in the presence of light, this process ceases in darkness. During a sunny day the leaves of plants steadily manufacture starch; while during night this ceases, and the manufactured food is passed downwards in the plant to the parts where it is needed.

Storage of energy.—To follow the matter one step further. The sun is the great source of energy. It is an old story that needs no repetition, how the sun drives our engines, lights our streets at night, warms our houses, etc., by virtue of the energy he has stored in coal layers which were growing forests thousands of years ago. When viewed in this light, each plant is a storehouse of energy, potentially capable of doing work—supplying strength to man and brute, building up its own tissues, breaking up gases to suit its own requirements.

In some cases this energy may be stored in the form of seeds, as in the case of cereals; and man uses certain of them to repair the energy he has wasted by work. In other cases the energy is laid up in tubers, in bulbs, or in roots; and again man appropriates it for his own use. Already we have seen how the plant uses this energy to enable it to perform work in the breaking up of gases that these may be used in the preparation of the food it needs. The remaining point to examine is what processes this food passes through as it leaves the leaf and more food is manufactured to take its place.

14. Appropriation of atmospheric oxygen.—Take a good handful of beans which have begun to germinate, or of rose-buds, and place them in a jar with a thermometer pushed in among them. Place in a dark cupboard for some time. Take the temperature of the air alongside the jar with another thermometer. What difference do you note in the readings of the two? What would you say is taking place among the bean seedlings?

Breathing of plants.—The readings of the thermometer prove that a little warmth is being generated by the growth of the seedlings. Now warmth usually implies burning as a cause.. Our bodies feel warm because our blood is heated by a slow burning which results from the use of oxygen supplied by our lungs: a fire gives heat because of the burning set up by the oxygen of the atmosphere as it passes among the wood or coal. In fact, in all cases of ordinary burning, oxygen is present in some form or another to support combustion, whether the burning be very slow and flameless, as in the case of our bodies, or quick and flame-producing as in fires. And in the case of growing seedlings, the rise in temperature is but a sign that burning is going on, very slowly to be sure, and this burning necessitates the using up of oxygen if it is to be continued.

Here then is another point—plants use up the oxygen of the air, and, as in the case of ordinary burning by fire, or of that burning which takes place in the bodies of animals, carbon dioxide is given off as a product. This fact was long hidden in the case of plants, because during the day the opposite process which we saw early in this discussion, namely, the using up of carbon dioxide by plants and the giving off of oxygen, is so marked as to mask what has just been described. During night, however, the former ceases, and the latter can easily be examined; but respiration, or breathing, *i.e.* the using up of oxygen and the giving off of carbon dioxide, is not limited to the night time but proceeds during the day as well.

Result of "burning" in plants.—The term "burning" implies destruction and the using up of fuel, and the fuel used in this case is part of the starchy matter present in the leaf. Part of this food, or stored-up energy, is used to build up the plant structure, and goes on doing work in the body of the plant; part may be stored up as starchy matter since there is no present need for it, and part is used as fuel in the process of respiration and does work immediately. It is by means of the energy set free by this process that the plant is able to continue to live, and should respiration and the resultant oxidation cease wholly, all these other processes which we have spoken of in this chapter also cease, and the plant dies.

The downward path of the manufactured food.—In the case where a branch of a tree was ringed of its bark, it was found that the upward movement of the water in the stem did not take place in the portion removed as bark, for the leaves continued fresh for some time. But if this experiment be allowed to stand for a year or two, it will be found that unless new leaves grow out from previously dormant buds below the ringed part, the branch will by and by die. Sometimes this is preceded by a marked swelling all round the bark just above the ring, similar to what occurs when a piece of tarred string or wire is tied tightly round a branch in spring and allowed to remain (Fig. 50). All this goes to prove that the downward path of the food takes place in the portion removed as bark. The starchy matter accumulates just above the ringed part as it finds no outlet downwards, while as no food can be carried to the part of the branch below the ring, this part gradually starves and ultimately dies. Naturally the result is that no moisture can then ascend this dead part, and the whole branch succumbs.

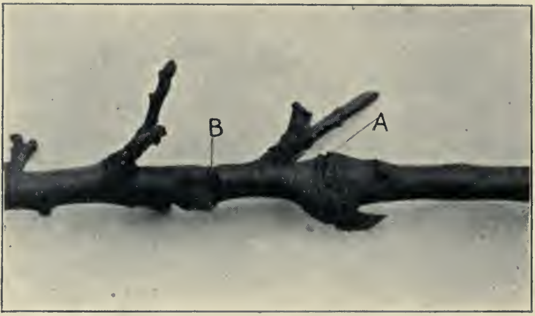


FIG. 50.—Apple branch photographed in Nov., 1912. A. Result of too tight tying in spring of 1911. B. Result of too tight tying in spring of 1912. Note peculiarity of growth at A.

Summary.—What has been kept in view in this chapter is the fact that the plant is a most delicately constructed machine, much more complex in its build and working than any machinery known to us, the parts being very closely connected functionally, though physically perhaps far apart, and the clogging or destruction of one resulting in the general incapacity of the whole. Not only is the action of this machine as a whole intricate and marvellous, but the working of each single part is the result of the co-operation of several natural laws whose importance is not at all evident from superficial observation.

This machine, too, does work. This work is directed towards the further building up of the machine itself and the storage of energy in the form of seed, tuber, bulb, etc., to the end that the species may not die out but be propagated in the coming year. Work implies the expenditure of energy, and this energy is derived from the starchy food manufactured in the leaves, which itself owes its existence to at least four different sources, *i.e.* the energy of the sun, the carbon dioxide of the atmosphere, the moisture which the plant draws from the soil, and the mineral substances contained in solution by this soil-water.

In addition to and largely apart from this, the plant is a living organism, maintaining its vital activity by a process of respiration, the result of which is that energy is set free by the combustion of the starchy matters; and just as in the case of animals, when this supply of energy is cut off or ceases, the functions of the different parts of the plant are suspended and death results.

CORRELATED EXERCISES.

1. It is sometimes said that animals, fires, etc., use up oxygen and give off carbon dioxide, while plants use up carbon dioxide and return oxygen to the air, thus maintaining the necessary balance of nature in the atmosphere. Is this the whole truth?

2. What differences should exist between the treatment required by a deep-rooted plant and that required by a shallow-rooted one?

3. What is meant by "the principle of osmosis"?

4. Describe carefully the position of the path of the ascending food-material and that of the descending food in an apple tree.

5. Why is it harmful to cut a branch from a growing plant in spring?

6. Plants growing in desert lands have leaves either thick and fleshy, or narrow and rolled round; many rock plants have their leaves covered with hairs; the cabbage has a kind of "bloom" on one side of the leaf which can be rubbed off with the finger. All these are developed for the same purpose. What is this purpose? Show how each fulfils its function.

7. Explain why fodder cut in the evening is more nutritious than that cut in the early morning.

8. Show how it is true that plants are the accumulators and animals the dissipators, of energy.

9. What substance used in the manufacture of its food does the cabbage obtain from the atmosphere? In what form, when, and under what conditions, is it taken in?

10. How would you prove that the stem of a tree derives food from the leaves?

11. Explain how it is that a lettuce plant, covered with a box and kept in darkness, loses its green colour.

12. Carefully examine a branch of a fruit tree which has been tied tightly to a support with a piece of string. Describe exactly what you note, and account for any variations in growth which appear abnormal.

13. Why do some garden-workers cut off a portion of the leafage of a plant in the operation of transplanting?

CHAPTER VII.

SUBSEQUENT TREATMENT OF CROPS.

1. Moisture-retaining capacity of soils.—Collect some sand, clay, garden-soil, and leaf-mould. Take four tobacco tins with small holes punched in the bottoms, or four pieces of perforated zinc cut into a circular form to fit half-way down into the mouth of a glass funnel. Place a layer of sand, clay, garden-soil, and leaf-mould respectively into each tin, making the layer about 1½ inches thick, and packing it tightly round the edge. Fix each above a beaker, and pour in slowly 10 c.c. of water.

Note in each case whether (1) the water passes through and drips from the holes in the bottom, (2) lies on the surface, or (3) is absorbed but is not allowed to drip. Add 5 c.c. more. Observe as above, and note. Again add 5 c.c., note; and after a little add 5 c.c. more.

Which soil allows water to pass most freely through it? Is any water retained? Find this out by measuring the water which has passed through. Which does not allow water to percolate, but keeps it lying as a pool on the surface? Why would this not make good garden soil? Which retains most water held in suspension? Find what proportion is thus held.

Which soil is most likely to run dry in summer? Which is the best kind of soil to have in a garden from a moisture-retaining point of view?

Moisture retained by the soil.—The amount of moisture which a soil will hold as water available for crops depends largely on the size of the particles of which the soil consists; as a rule the smaller the particles the more moisture is held in suspension. The largest particles of all are found in sandy soils, and as the total area of particle-surface is small, comparatively little water is held in suspension. This is soon used up or evaporated, and drought sets in. Clay soils, on the other hand, are composed of particles so small that water takes a very long time to pass downwards, and thus lies as pools on the surface. Such a soil of course is very wet in winter, retains its wetness far into spring, is therefore late, and when it does dry—chiefly as a result of evaporation—splits up in great cracks, ruining the roots of the growing crop.

But a soil containing much humus acts as a sponge to water. As many of the particles are very small, it presents an enormous area of particle-surface for water to cling to. Thus this soil does not allow much to drain away, but retains a very large percentage as suspended moisture. If the garden-soil and leaf-mould be left in position for 24 hours or so, it will be found that more water has drained away. In fact such soils retain a large amount of rain in the surface layers which contain much humus, and slowly pass this moisture downward to the lower layers where the deeper roots of the crops are benefited. All this suggests that the greater the percentage of humus in a soil, the less fear there is of drought, and that one of the aims of the garden-worker should be to increase the proportion of this matter in the soil. The method of finding the proportion of humus existing in a piece of soil has already been described (p. 29).

2. **Mulching.**—Lay off four plots of ground, each about 4 feet square, in an open part of the garden, in the full glare of the sun, and if possible where they are not sheltered from winds. If such soil is not to be had inside the garden ground, perhaps the necessary space may be had outside. Label the plots *A*, *B*, *C*, *D*. Cover *A* with long or fresh manure to the depth of 1 inch or more. Give *B* a similar covering of hay. Thoroughly surface-hoe *C* to the same depth, keeping the top soil as loose as possible, while *D* is left uncovered and untilled. Allow a week to elapse, and then carry out the following investigations.

Remove the **mulch** or loose covering of manure, hay, or soil, in each case, the soil-mulch as well as the other two, from a space 6 inches or so square. Dig down about 3 inches, removing this part of the soil. Remove about a handful of the soil below this. In the case of plot *D*, dig down about 3 inches from the surface and act similarly. Keep the handfuls of soils separate and labelled.

Now weigh immediately 10 grams of each in its present moist condition, and place it in a crucible. It may be air-dried by spreading it in the sun for some time, or the crucible may be set in a much larger crucible which is filled with dry sand, and heat applied until the soil is dry. Now weigh. Account for the loss of weight. Tabulate the results, arranging the soils in the order of the greatness of their moisture-content. Replace the soils and the mulches.

Again remove the mulches from a different portion of each plot, removing the soil-mulch as well. Insert a thermometer in each plot to the depth of about 4 inches, covering with a collar as already advised for the taking of soil temperatures (p. 2). Insert the thermometer about 3 inches deep from the surface in the case of plot *D*. Leave for three minutes at least. Withdraw the thermometer, read quickly, and record. Which soil is warmest? Which is coldest?

Carry out these investigations once per week for several months, or once per day for a week at intervals, beginning just after seed-sowing time and continuing throughout the hot weather. Do you notice any change in the results between those of spring and those of mid-summer?

When the sequence of readings is completed for several months, the readings being taken at the same hour each time, preferably about or a little after mid-day, plot the results as graphs of four lines showing the temperatures of the four plots on one sheet. The results will be much more marked than if the readings of each plot be put upon a separate sheet. Do similarly with the moisture-content readings. Do you note any similarity between the graphs?

Conservation of soil-moisture.—It has already been explained that, in proportion as moisture is evaporated from the surface layers of the soil, the water from below ascends by capillary attraction through the pore-spaces and is in turn evaporated. This may proceed until the particles of the soil are robbed of practically all their moisture, which in this way benefits the crop to no extent whatever. But it has also been explained that if spaces exist in the surface soil too large to permit the water to be carried across to the next soil-mass, this ascent of moisture ceases. This fact may be made use of in the growth of crops to husband the soil-moisture and prevent needless loss by evaporation.

When seeds are sown, they lie for the most part in the surface layer, and that they may germinate freely with a sufficiency of moisture, the soil is well packed. This results in free passage of moisture to the surface, and the supply of water for the seeds is thus continuously maintained. Incidentally it also causes a considerable loss of moisture from the soil by evaporation, as this ascent is continuous; but the gardener must submit to this loss in order that the seeds may germinate. Such loss, however, is only temporary and after all is not very great, for in early spring the strength of the sun-heat is comparatively small. Once the plantlets have rooted, a moisture-supply in the surface is no longer needed. The roots are penetrating downwards. Few are close to the surface, and the gardener's purpose is to prevent soil-moisture from rising to the surface and passing away as vapour. In fact, he adopts methods to retain the soil-water in the middle and lower layers of his ground.

Summer examination of soil which has been mulched with manure, hay, or soil, will show that, in every case, ground which has been mulched contains more moisture at a depth of 4 to 8 inches than soil which is left uncovered, and what is of consequence is that this is the region where a large number of the roots of ordinary crops are to be found. The moisture held by manure, hay, and the surface inch or so of loose soil, has certainly been lost by evaporation, but between the manure and the soil exist air-spaces so large that capillary water cannot pass across them. Thus evaporation ceases and the soil underneath retains the moisture it holds.

These air spaces may not seem large to an observer; in fact the manure, hay, and loose earth seem to lie in close contact with the soil, but nevertheless such spaces as do exist are very great indeed compared with the capillary air-spaces of the soil, too large in fact to allow water to pass across by capillarity.

This implies that by mulching the ground the garden-worker is able to a large extent to conserve the moisture which the land contains, and in the case of sweet peas, bush-fruits, etc., a manure or grass-mulch is often used. To attempt this in the case of vegetables is of course well-nigh impossible on account of cost, but in this case a soil-mulch has been found to be almost as efficient. Consequently when the plantlets once begin to grow, the gardener should seize the opportunity to begin at once to loosen the surface soil and thus form a mulch. It may be almost impossible to use a hoe for this purpose during the early stages of the plant, and so a piece of stick, or a "digging-stick" (Fig. 51), should be used, care being taken that no soil is disturbed within a couple of inches on either side of the row of plants. Later the hoe should be used for the purpose. The whole of the upper inch or so of soil should be thus loosened so as to form a soil-mulch. As the season advances, the depth of the mulch should be increased to 2 or even 3 inches, for one operation is not by any means sufficient for a whole season. A shower of rain, the settling down of the soil, etc., may cause capillarity to be restored, and surface loosening of the soil will be found necessary at least once per week during the period of growth. Such mulching should be done in the case of all crops whose growth will permit, and is especially valuable in the case of roses, fruit trees, and fruit bushes. It has also the virtue of keeping down weeds.

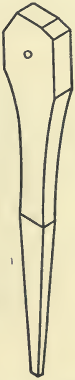


FIG. 51.—Sketch of digging-stick. 7″ × 1″ × ½″. Material—Larch.

Effect of mulching upon moisture-content and temperature.—In addition to all this, it will be found that the temperature of mulched soil at the depth of 6 inches or so, is lower during summer months than that of uncovered soil at the same depth. This is easily explainable by the fact that mulched soils contain more moisture than unmulched soils. Water requires more heat to raise it by one degree of temperature than does earth. So that by mulching ground with manure, hay, or soil, the garden-worker provides for his crops a moister and a cooler soil than if he does not mulch, *i.e.* just the conditions required by plants in hot, dry weather.

3. **Weeding.**—It is quite unnecessary to allow any part of the garden to become weedy for the sake of experiment. In the first place, it would become a danger to the rest of the ground by seeding, and in the second, the student unfortunately has not to go far on his rambles ere he comes across a patch which suits his requirements perfectly. All garden-workers are not equally careful to permit no growth of weeds, though were they once convinced of the harm such a crop does, no doubt they would very quickly change their method of working. As has been already remarked, any plant growing where it is not desired

must be considered a weed. Therefore all the common weeds of cultivation are here included, as well as any garden plant coming up where it is not wanted. For example, a potato plant growing among a row of peas is certainly a weed, and should be treated as such.

Effect of weeds upon crops.—Certain points we have already found out regarding the growth of plants are of help to us in determining how it is that weeds have a bad effect upon crops. Plants for full development require an abundance of atmosphere, light, moisture, and food-material. But as weeds grow up they overshadow the crop, cut off the supply of light, hinder the free play of the atmosphere about the leaves, and rob the crop of moisture and food-material. Thus one or other of two things happens. The crop becomes dwarfed and sickly-looking, or strives to force its way up to light and air, thus running all to length and defeating the ends for which it is being grown. Apart from all this, weeds look bad, are generally the sign of bad gardening, and from time immemorial have been handed down as the special sign of that unpleasant type of character—the sluggard.

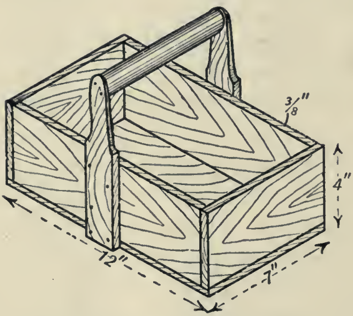


FIG. 52.—Sketch of weed-basket.
Material—White wood or home-grown pine.

But weeds will grow in the best-kept garden. All the worker can do is to pull them out as they appear. Now they are plants, and are therefore built up of materials derived from air and soil, so they contain just those elements which crops require as food-material. On this account they should not be lost, but used to form a compost heap in an out-of-the-way corner of the garden.

Watering.—An examination of the number of gallons per plot represented by even one-tenth of an inch of rainfall may be seen from an examination of the rainfall table on page 50, and the futility of attempting to apply an equal amount of water with a watering-can is thus made obvious. This difficulty is increased by the fact that rain falls much more gently during the growing season than does water from the rose of a watering-can. In the former case the soil becomes gradually soaked, drinking in every drop as it descends. In the latter case the pore-space in the surface soil quickly becomes filled with moisture, more is applied before this water can percolate downwards, the surface pore-space is incapable of holding more, and the result is that the water applied flows away over the soil in a series of little rills, and is lost to the crop. Indeed, it is a question whether much is to be gained by general watering of a garden, if a surface mulch is carefully maintained.

True, there are plants which to bring to full maturity it is absolutely necessary to water—cabbages, lettuce, and sweet peas, for example—and in their case the use of a watering-can is essential. In planting any of the cabbage family, the correct method is to leave a slight depression right round the stem of the plant, and to pour water into this hollow at intervals. This is the best means to employ in watering any plant, pouring it in at the roots and giving a thorough drenching at intervals rather than applying driblets often. With the latter plan, that which is applied seldom reaches the roots of the plant, being evaporated before it has time to percolate downwards. In very dry dusty weather, a thorough washing of the leaves, towards the close of the day, is good for most plants, as it washes away all minute particles of dust, which otherwise clog the stomata and retard the functions of the leaf.

Liquid manure is not applied for the purpose of watering the crop. It is used for the food-materials it contains. If the soil be very dry at the time of application, a thorough drenching with water should be given first. Otherwise the solution will exist in the soil in too concentrated a form, will cause a flow of plant-sap outwards from the root-hairs rather than a flow of soil-moisture inwards, and thus render the plant limp and possibly cause death. This action is discussed at greater length in the chapter on manures.

4. Liquid manure can be made very easily by suspending in a barrel of water a bag containing a few forkfuls of farmyard manure. The bag is allowed to remain for a day or so, when the liquid manure is ready for use. If the colour is darker than that of weak tea, the liquid should be diluted with water.

This liquid will contain a large part of the soluble matters existing in the manure, and these are therefore in a condition which renders them fit for immediate use by the plant. It should be applied only to gross feeders, cabbages, lettuce, raspberries, roses, etc.—in fact, the first mentioned can hardly be brought to a perfect condition without some such treatment. But frequent applications may be harmful, rendering the soil-moisture too concentrated; once per week is often enough. Fig. 53 shows the result of the application of liquid manure even to a lupin, which has the power of appropriating the nitrogen of the air by means of the nitrogen-fixing bacteria found in the nodules seen on its roots (Fig. 67). The plants were of the same variety, and were of about equal growth to begin with; *A* received no liquid manure, *B* received a supply of liquid manure once per week. The result, as is evident from the photograph, is very marked.

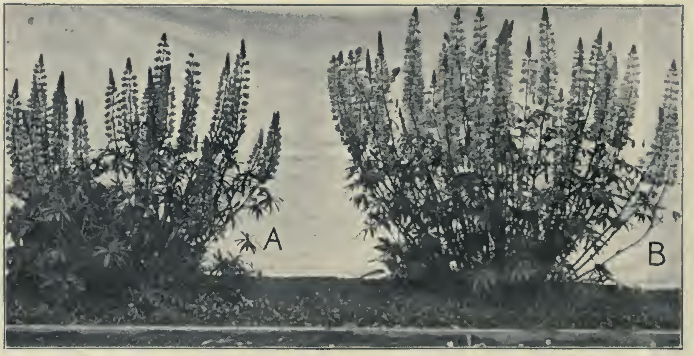


Photo Mr H James

Fig. 53.—The effect of liquid manure upon two lupin plants. *B* received liquid manure once per week. *A* received none. The plants were about equal to begin with.

5. Thinning-out.—The usual advice given with regard to this operation is, "Thin-out the plants as soon as they can be handled," and more definite directions are rather difficult to give. Plants may be thinned as soon as possible after their second pair of leaves appear. It is usually better practice to leave but a small space—a couple of inches or so between the plants in the first thinning, later thinning them out to the required distance in each case. This plan prevents blanks which result from dying off from diseases, etc. In almost every case, save where specified later, strong sturdy plants should be retained in the last thinning, the weak and straggling being pulled out. Leave no thinnings on the garden ground. The compost heap is the place for them, save where, as in the case of lettuce and radishes, some may be fit for use.

The subsequent treatment of each crop grown in the garden plot will now be discussed. It is understood, of course, that, except in the case of potatoes, and of cabbages when they are earthed-up, a thorough stirring of the surface soil takes place once per week, and should a heavy shower of rain cause the earth to settle down, the mulch is renewed as soon as possible. Also, it goes without saying (though not without a considerable amount of work), that the plots are kept free from weeds.

6. Beans (broad).—Protect from birds by the use of black thread. When the plants appear, earth them up a little as a support.

Cut away all stems save one, retaining the strongest. Support by six stakes to the 9-foot row. Tie stout string from stake to stake. Apply liquid manure once per week. When the flowers are well set, pinch out the growing tip (say) a piece 1 inch in length. Pull the pods while they are young and tender, on no account allowing them to ripen.

One stem only is retained, as the supply of food material from the roots is thus concentrated upon a smaller amount of growing tissue, with the result that larger and better filled pods are obtained. These single stems need support, for, being of little diameter and burdened with a weight of pod, they are easily blown over and broken by wind. As they do not cling, either by stem or by tendrils, they are supported on either side by lines of stout string. The plant is a gross feeder, so that it responds well to the application of liquid manure.

The pinching out of the growing tip is done for two reasons. In this way further increase in length of the stem is arrested, and the strength of the plant is thrown into pod-formation on the part of those flowers which are already well formed. In addition, it must be remembered that the black aphis, perhaps the worst pest of the plant, appears first upon the growing tip. The soft young tissues of this part are especially suited to their requirements, and if it be pinched off before or just when the first signs of the aphis appears, the aphides find no part of the plant which suits them, and thus an attack is averted.

7. **Beans (French).**—Protect as for broad beans. If necessary, branchy twigs about a foot in length may be used as support. The pods of this bean are eaten, so they should be gathered while they are tender.

8. **Beans (scarlet runner).**—Apply liquid manure once per week. Support by growing to a round pole about 9 feet long and little more than 2 inches in diameter. Grow two plants to each pole. If runner beans are grown on a trellis work, they should be planted well apart, say 12 inches, and the tops pinched out when they have reached the required height. Pull the pods young, as in the case of French beans.

As the runner bean does not climb by tendrils like the pea, but twines its stem round and round what it clings to, the best form of support is a pole of small diameter. Two poles with two plants to each are usually sufficient for each plot. The pinching out of the growing tips of plants grown on a trellis results in further growth in length being stopped. Buds which have hitherto remained dormant thus receive and make use of food-materials, start into growth, and develop into side branches which bear flowers and fruit.

9. **Beet.**—Take great pains to thin-out so that only one plant is left in each case. Give thorough drenchings with water occasionally. The globe-shaped variety should be pulled and used immediately a fair size is reached. The seedlings of the long variety are thus left 8 inches apart. The plants should be removed from the soil just before frosty weather sets in, care being taken that the root is not bruised. Use a digging fork for the purpose. Cut off the tops, leaving about 3 inches of leaf-stalk above the crown. Store in dry sand or in a pit.

The "seeds" of beet which are sown are really fruits, each containing two or more seeds. Consequently the plants come up very quickly together, and much care will be necessary at the early stages to ensure thinning-out to one plant. This is very important; that it is difficult, experience will show.

As two varieties are being grown in one line, both must be considered. The globe-shaped beet is shallow-rooted, and seeks its food-material in the surface few inches. The long beet is deep-rooted, and thus seeks further afield. Therefore the globe beet may suffer from drought, to which danger the long beet is not so open, and as shortage of moisture means arrested growth, the line of beets should receive thorough drenchings with water occasionally, and a soil-mulch should be formed after water is applied.

Arrested growth causes the plants to develop woody tissue, *i.e.* to become stringy, in which condition they are unfit for the table. A time comes, of course, when growth naturally ceases, and if the round beet be left in the soil until this occurs, the soft, pulpy flesh begins to change to wood as a preparation for winter, and the plant is then past its best. Therefore they should be pulled when they reach a fair size. Thus the globe-shaped beet occupies the soil for but a short period, and when these roots are pulled those of the long variety are left 8 inches apart.

Care should be taken that the root is taken intact from the soil. Otherwise the plant-sap naturally finds exit by the wound and is lost. The beet is then said to "bleed." Bleeding will take place also from the root if the leaf-stalks are cut away close to the crown.

10. **Broccoli.**—Firm the soil well around the roots, and then maintain a surface-mulch. Should the plants appear to be making little progress, apply a little liquid manure, but be careful to gauge the quantity supplied, so that no luxuriant growth of soft leafage results. Aim at a stocky, sturdy plant.

"Heel-in" at the right time. This operation consists in removing a spadeful of soil from the north side of the plant, placing the spade well home at the south side and forcing the plant over until it lies with its head pointing to the north. Replace the soil around the plant, pack it well home, and bank up the earth until the stalk is covered with soil right up to the base of the leaves. Use the heads as they are needed.

The whole of the cabbage family are gross feeders, but liquid manure should be applied to broccoli only when they show signs of being backward in growth. Otherwise there is danger of causing much leafy growth, which hinders the development of the head and weakens the plant for the winter frosts. Thus firm, stocky growth is what is wanted, and this is encouraged by packing the earth around the roots. This would result in loss of moisture by evaporation, so a soil-mulch is maintained on the surface.

The danger in the case of broccoli is not so much in frost alone, as in alternate frost and thaw. When this has occurred a few times, the head becomes a soft, watery, decaying mass. The tissues have been torn asunder by the frost and the succeeding thaw, so that this part of the plant ceases to function, and dies. Frost cannot very well be prevented, but thaw can, and this is accomplished by the process called "heeling-in." By this method the plant is placed with its head pointing to the north. Thus it may freeze, in fact most certainly will; but as the rays of the winter sun cannot strike upon the open part of the head, little thawing takes place.

11. Brussels sprouts.—With this crop, as with all the cabbage family, if signs of "club" appear (Fig. 54), either pull up the plants and burn them, or earth them well up and supply with plenty of water, burning the root after harvest. Do not apply any liquid manure to Brussels sprouts. In South Britain the side lower leaves should be broken off, but in the north this must not be done. Gather the lowermost sprouts first and the head last of all. Often a second crop may be gathered.

Earthing-up often enables the garden-worker to bring members of the cabbage family to maturity when he would otherwise have no crop. Should the lower part of the root be attacked by a disease, the ordinary supply of soil-moisture is denied to the plant, and growth will cease. If the stalk has been well earthed-up, however, the plant has the power to develop adventitious roots higher up than the diseased part (Fig. 55, in which case the plant was attacked by the cabbage grub-fly), and these may be able to supply sufficient food-material to the plant to bring it to harvestable size.

Brussels sprouts are wanted hard and compact, so that the application of liquid manure is not advised, as it encourages soft, leafy growth. Southern growers break off the lower leaves, evidently with the purpose of thus throwing more strength into the sprouts. In the north this is not done, as a matter of protection. Leaving the top to be gathered last of all also results in additional protection being afforded to the side shoots. If these are broken off carefully, second growth is almost certain. This is due to the fact that buds which up till now were dormant for lack of food-material, air, and sun, have full supplies of these when already-formed sprouts have been removed, and so they start into growth.

12. Cabbage.—Supply spring-planted cabbages liberally with water and liquid manure, and give an occasional light top-dressing of nitrate of soda. Eggs of the cabbage butterflies found on the backs of the leaves should be destroyed, some being kept for examination purposes. Look for caterpillars and destroy them. A general limpness of the lower leaves is a sign that the cabbage root-fly is at work. Earth-up well in such a case, and supply the plants generously with water. Treat for the pest as advised in the chapter on plant diseases and pests (p. 273).

As will be found in the chapter on manures, nitrogen is intimately connected with leaf development, and no cultivated plant makes leaf-formation more its chief business in life than does the cabbage. Thus much nitrogen is needed, and it is supplied by the application of liquid manure and nitrate of soda. In addition, much leafage implies a very large number of stomata with a proportionately excessive amount of transpiration. Therefore much water is needed. This must be kept up throughout the growth of the crop, for at no period in the life of the plant does much leaf-formation cease.

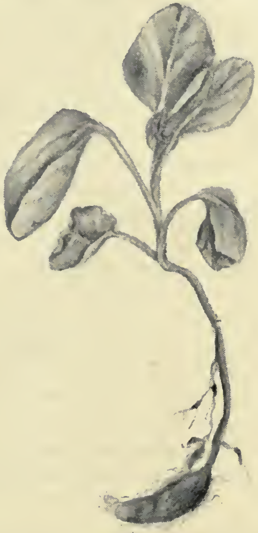


FIG. 54.—"Club-root" in young cabbage.

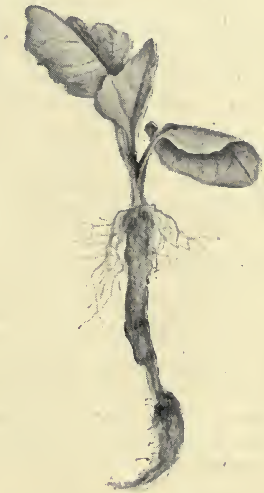


FIG. 55.—Growth of adventitious roots above diseased part. The result of earthing up and much watering.

13. Carrots.—Thin-out as soon as possible, at any rate by the time that the plants are two inches high, taking care that no bruised thinnings are allowed to remain about the plot. Pack the soil as tightly as possible around the plants which are retained, covering the crown with earth. Water well, spread a little guano along the row, and then sprinkle a solution of sheep-dip down the row on either side of the plants. Continue packing the soil and applying dip until the crop is out of danger. A second and perhaps a third thinning may be necessary, and these thinnings may be used, but not within a fortnight of the application of dip, or they will taste of it badly. Use as required, or store before frost comes on.

The less disturbing of the soil the better during thinning operations in the case of carrots, therefore the plants are thinned as soon as they can be handled. As already mentioned, the great preventive of the production of a good crop of carrots is the carrot-fly (Fig. 90). The fly lays its eggs in the ground close to the crown of the plant, and if the soil be loose and open, conditions are most favourable for the insect's finding an easy passage to the spot. When the soil is well packed above the crowns, this opportunity is not given and the fly is at a disadvantage. Sharp, continuous growth also places the carrot in a more favourable condition for resisting this pest, as in most cases the attack begins while the plants are very small and the outside tissues thin and delicate. A sufficiency of water and a top-dressing of guano tend to produce such steady growth, as the plants thus receive a continuous supply of food-material.

Thinnings and bruised plants allowed to remain upon the plot seem to attract the fly by means of the smell, and of course they should be removed and covered with earth. As the insect seems to be sensitive to smell, this may be the secret of the success of a solution of sheep-dip as a preventive. The great objection to this solution is that it has a strong influence upon the cooking value of the carrots, unless a sufficient time elapses between application and harvesting.

14. Cauliflowers.—Apply liquid manure once per week, plenty of water, and an occasional top-dressing of soot. Shade the head by drawing two or three leaves over the top and tying them in position with bast. Cut when the head is at its best, *i.e.* before the "curd" becomes uneven. Treat for root-fly as in the case of cabbage.

Though gross feeders, cauliflowers may have too rank growth encouraged if the supply of liquid manure be over-abundant, especially if the ground has been heavily manured for the crop. Best results, indeed, are sometimes to be had by giving no application of farmyard manure to this vegetable, but setting the plants in soil which was well manured in the previous year, and regulating the food-material by the supply of liquid manure and soot.

15. Celery.—Apply much moisture and large quantities of food-material. Use liquid manure made as already advised, or a liquid manure made of artificial fertilisers. Indeed, these may be used alternately. Two ounces of superphosphate, one ounce of nitrate of soda and one of nitrate of potash, two gallons of water to each, answer well. Tie the plants up loosely with bast to keep them from spreading, and cut out all suckers. About eight weeks from the time the plants are required, they should receive a first earthing-up. This should be done three times, filling the trench to the level of the surrounding soil in the first operation. A fortnight later earth-up again, and in another fortnight apply a final earthing-up. Great care must be taken that no earth enters the heart of the plant during these operations, or decay is likely to ensue, so the leaf-stalks should be held together with the left hand and the right used to heap up the soil. Cover the plants over with long manure or grass during the winter.

Crisp growth, free from stringiness, is required if this plant is to be well grown, so not only must there be no arresting of growth, but food-material and water-supply should be abundant. Again, as in the case of cabbages, we have a plant which transpires much moisture as a result of great leafage, so the soil must be kept very moist. This naturally results in the earth around the roots being kept cool, *i.e.* just the conditions favourable for luxuriant growth in warm weather.

The leaf-stalks are earthed-up in order to "blanch" them. This is brought about by the exclusion of light, which results in the lack of formation of chlorophyll or green colouring matter. The plant, however, still possesses in its uncovered leaves the necessary apparatus and conditions for the manufacture of food, and this proceeds although the lower parts of the stalks become devoid of green colouring matter.

16. Leeks.—Transplant as soon as the leaf takes on the "flag" appearance, *i.e.* when it broadens out. Lift the plants from the seed-bed by loosening them with a fork. Cut back the roots to within 3 inches of the bulb, and similarly reduce the leaf in size by cutting a piece off the growing tip. Make a hole 9 to 12 inches deep with a dibble, drop the leek in, pour in little or no soil, but leave the hole quite open. Fill up the hole with water and after a few days apply liquid manure. Still leave the hole quite open, so that liquid manure and water may be applied without difficulty. The plant is quite hardy and stands frost well. Cover over the crop with some rough litter just before the winter frosts come on, so that the earth may not become too frost-bound to permit of harvesting. Dig up the plants as required.

Leeks must be transplanted if they are to attain their best, because for this they require room for full development, and as much as possible of the plant must be blanched. This is easy of attainment on account of the fact that the plant is hardy, bearing transplanting very well, and in addition, as it stands almost any degree of frost, it occupies the ground for such a length of time that its period of growth is extended far into late autumn and early winter.

In the process of lifting from the seed-bed the roots of the plants become much torn and broken. These must be dressed back to a clean-cut end, and with such a number of roots the most expeditious method of accomplishing this is cutting all the roots back to the length of the shortest. That this treatment does not hinder the plant's activities is explained in the chapter on fruit trees and bushes (p. 229). But when treated thus the leek enters the soil lacking many of the organs which have previously absorbed moisture for the use of the plant. Thus the supply of moisture is lessened, while this defect is not balanced by any decrease in transpiration by the leaves if these be allowed to remain at their present size. Thus loss proceeds at a rate so great that the roots cannot make good what the plant transpires. If a part of the leafage be cut off, less transpiration-surface remains on the plant, and a balance is maintained.

17. Lettuce.—At the seedling stage, lettuce are especially acceptable to birds and slugs, and therefore need careful watching and protection. Soot against the latter and black thread against the former will be found effective. Supply the plants with plenty of water and liquid manure. Maintain a soil-mulch, steadily renewed. Top-dress occasionally with nitrate of soda. Use early thinnings. Thin-out finally to 9 inches apart.

Lettuce grow best when the soil is kept cool and moist; and as they occupy the ground usually for a short season, care should be taken that growth is continuous from start to finish, and that no stoppage of growth occurs as a result of drought. This is accomplished by the use of much water and liquid manure, with an occasional slight dressing of nitrate of soda, as the plant is grown for its leafage.

18. Onions.—Compact the soil at intervals during the period of growth, forming a soil-mulch immediately afterwards. Thin-out to from 6 to 9 inches apart according to the size of bulb wanted. Place thinnings in the compost heap if they are not used, and thoroughly cover them up. Apply top-dressings of fowl droppings and wood ash, worked into the surface soil with a rake or digging-stick, taking care that the roots are not disturbed. Harvest in September. Ripening may be hastened by bending over the green tops, though it is maintained by some gardeners that this spoils the flavour. In any case do not harvest until the crop is quite ripe.

Harvest by removing the soil from around the bulbs, thus leaving the plants in their places, but somewhat loose. When they have remained thus for a few days, pull them up. Clean away all traces of soil from the bulbs, and then lay the plants in the sun, taking them inside at night until they are quite dry. Rope them up in strings and hang them so that they are quite dry and free from frost. Examine at intervals, and remove all bulbs showing signs of disease or of softening.

The necessity of compacting the soil in the case of plants in which firm, sturdy growth is more desirable than luxuriant leafage is dealt with elsewhere. Only by such packing of the soil can firm onion bulbs be obtained. But the onion needs, above all, a cool, moist soil, and this is to be had only by maintaining a thorough surface-mulch. Therefore, immediately after the soil has been well packed alongside the plants to make it firm underneath, the surface should be well hoed to retain soil-moisture.

It seems that just as young children are especially liable to certain diseases and seldom suffer from them when they grow older, so the onion plant has ills peculiar to its early tender-skinned existence, and the onion-fly attack (Fig. 91) is the worst of the lot. When the plant has once made a good start, however, it is not nearly so liable to seizure; so growers bend their energies to having the onions fairly well grown by the time warm weather brings out the fly and sends it on its mission of destruction. Gardeners have been successful in the following ways, each resulting in the production of a plant of fair size by early summer.

Onion "sets" or bulblets are now to be had, which are planted by the garden-worker in spring at the same time as shallots. These are, of course, dormant plants. They were obtained by sowing seed thickly on light, dry soil. These grew up, and being at decided disadvantages with regard to food-material, room, moisture, etc., remained stunted (usually from half to three-quarters of an inch in diameter), quickly completed their existence for the current year, and set as bulbs. When planted in spring the bulbs resume growth and give a good early crop, upon which the fly has little effect as a rule.

Another method commonly practised is sowing in August and transplanting in early spring, when the plants are at a good size. These do not suffer from fly attack as a rule.

A third method is to sow in heat in January or February and transplant as soon as the condition of the ground will allow.

Onions are largely surface feeders, so that they are apt to exhaust the food-material at their disposal unless top-dressing be resorted to. Especially does the crop respond to potash, and any available wood ash should be worked in among the growing plants.

19. **Parsley.**—Keep the soil moist and cool by watering and maintaining a surface-mulch. Thin-out to 9 inches, and gather leaves in about three months from sowing time. To preserve the plants during winter, they should be protected with matting, which should not lie upon the leaves so as to crush them, but be supported by some frame-work of wood.

Parsley needs a cool, moist soil which is at the same time well drained. Drainage has already been attended to, and all the garden-worker can do now is to maintain a soil-mulch. Parsley is a biennial, sending out foliage the first year, next year producing flowers and fruit. By cutting back the flowering stems some manage to make one sowing persist year after year, but the flavour of the plant is much impaired by this method. It is best cultivated by sowing once per year at least, and some even make two sowings. Best growth is obtained from plants grown in a seed-bed and transplanted. This crop makes quite a pleasant edging to a path if well grown.

20. **Parsnips.**—Thin-out as soon as possible to 4 inches and later on to 8. Place the thinnings on the compost heap. No watering is necessary, but a soil-mulch should be maintained. Lift as required, but on the appearance of frost cover the plants with a layer of long litter.

Thinnings of parsnips are of no use for the table, as the plant is not at its best until it has received a touch of frost. Being a deep-rooted plant, it is not likely to suffer from lack of moisture so long as a surface-mulch is maintained. They may be allowed to remain in the soil during winter, as are leeks.

21. **Peas.**—Protect from birds by means of black thread. If a very early crop is desired, the plants should be permitted to remain if they come up thickly, but otherwise thin them out to at least 2 inches apart. Earth-up when they are about 3 inches high, and again just as they

begin to show tendrils. When these appear, stake with twiggy branches about 18 inches long if they can be obtained. Later support with long stakes or wire netting. Stakes must be at least a foot longer than the height to which the variety of pea grows. Sink as much as possible of this foot-length into the soil, and to facilitate this the stakes should first have their bases pointed by means of an axe. Let the general direction of the stakes be vertical, upon no account permitting them to meet at a point at the top. If stakes cannot be obtained, wire netting should be used. Set posts of sufficient length firmly at either end of each row, and a few at intervals along the length. Stake with either two rows of netting, or one stretch of netting supplemented by stout string on the other side. Fix the netting on that side of the row which is to leeward of the prevailing summer winds. If no winds give trouble, fix the netting to that side of the row which receives most light.

Keep the row quite free from weeds, maintain a good soil-mulch, and drench the roots with water occasionally. Apply liquid manure once per week should the crop show any signs of backwardness.

Allow no pods to ripen. Each day pull a few of those which appear to be full enough. When the crop is finished, remove all "straw" from the garden, collect and clean stakes or wire netting, and store for the following year.

More than all other seedlings peas must be protected from birds, for an early-morning raid of a dozen sparrows will wipe out all hopes of a crop for the season. If plants be permitted to come up thickly, they quickly set in fruit as a result of the unsuitable conditions under which they grow. For a strongly-growing, healthy, long-lasting crop, a distance of at least two inches between the plants is necessary if they are to have sufficient food-material, light, and air.

Peas require support as their stems are thin and weak, and this support should be begun as early as possible. A ridging-up of soil gives both protection and support at the early stage; but the appearance of tendrils is an indication that the plants require something to cling to. If only large stakes are used these are usually lacking in twigs in their lower parts, so the plants, failing to receive the support which they require, bend over. As part of the stem thus lies upon the earth, it is apt to decay. Small twigs inserted among the plants will enable them to get a first start, and effectively prevent the stems from trailing upon the ground.

The larger stakes should be inserted so that they do not meet at a point right above the row. If they do meet, the plants are crowded together in a small space when they grow taller, and thus do not receive sufficient light and air.

One thorough soaking of water once per week is preferable to driblets given even twice per day, as small quantities naturally must be suspended close to the surface of the soil and be quickly evaporated. Liquid manure must be used with judgment, for over-application is apt to result in the growth of too much "straw."

Ripe pods are not acceptable for table use, and besides, a ripening pod, as in the case of sweet peas and beans, prevents the formation of new pods, owing to the fact that a severe strain is being placed upon the plant by the formation of fruit and seed.

Many growers encourage early fruiting by pinching out the growing tip when the flowers are well formed. This does not result in decreased crop. Further growth in length is arrested, and the result is that development is encouraged in the pods already partly formed, while side-shoots develop into branches in consequence of the increased food-supply they receive. The side-branches bear a later crop.

22. Potatoes.—Remove all weeds as they appear and maintain a soil-mulch. Care must be taken in weeding that the stems of the crop are not injured. Allow but two stems to come on each plant, breaking away all others. Earth-up first when the stems are about 4 inches high, and if night-frosts are to be feared, cover them right over the growing tips with earth. When the tops have made about 6 inches more of growth, earth-up again, thoroughly pulverising the soil in the operation. Care must be taken that the roots of the plants are not carelessly exposed, or they will be dried up and growth will be hindered.

About the end of June apply Bordeaux mixture as advised in the chapter on plant diseases (p. 276). A fortnight or three weeks later, give a second application, and about the middle of August a third may be necessary.

Lift the crop when the tops are ripe. Early potatoes may be taken as soon as the tubers are fit for use, *i.e.* when they are about the size of hens' eggs, but later kinds should be allowed to ripen unless they are to be used as "seed." In this latter case they should be lifted before they are quite ripe, and allowed to green for some time in the sun previous to being stored.

Lift the crop with a digging-fork, the tool being worked from the side of the drill and pushed under the plant. The whole is then thrown over, the tubers gathered, dried, cleaned from soil and stored in a pit. All diseased tubers and diseased stems must be burnt.

In pinching out unnecessary stems, weak growths should be broken off, only the strongest being retained. Gardeners who grow potatoes for exhibition allow but one stem to each plant, but in ordinary garden culture this is unprofitable, as a larger number of tubers is produced by two On the other hand, should half a dozen stems be left to each plant, the result must be that although the tubers produced are more numerous, they cannot but be much smaller than is desired for good potatoes for table use.

Earthing-up is valuable as protection in the early stages of the plant, as thus the effects of drying winds are not experienced by the stems and leaves. Some growers protect early potatoes from May frosts by covering them at evening with matting or bracken, thus retaining the heat of the soil. But the better method is to have the tubers well budded beforehand, and plant them late enough to escape the worst frosts. Even drenching the ground and tops with water in the evening has been employed in calm weather with good results. The air just above the potatoes thus becomes laden with moisture, which acts as a blanket, preventing the escape of soil-warmth by radiation. Frosty nights at this time of the year are usually still nights, and thus the atmosphere above the plants is not moved much by wind, so that the vapour-blanket persists throughout the night.

In the process of earthing-up, the soil should be thoroughly broken up, for if it forms a stiff, lumpy mass it thus hinders the tubers from swelling uniformly. Too much stress cannot be laid upon the necessity of taking care that roots are not disturbed, for the plants are thus robbed of part of their apparatus for absorbing moisture and food-material.

Earthing-up is necessary if a large crop of eatable tubers is to be obtained. In the first place, only those side-stems which are underground can produce tubers, so that, within limits, the greater length of stem covered over, the greater is the possibility of a large number of tubers. In addition, it will be found from examination of the row of potato plants in the experimental plot which has not been earthed-up, that by washing away of soil-particles by rain, by the growth of the tubers as they swell, etc., many of the tubers are exposed to the sun and air. These invariably become green in colour, *i.e.* begin to assume part of the characteristics of an above-ground stem, and are thus useless as food. Thus every tuber produced by the plant must be carefully covered over with soil if the garden-worker is to make good use of every foot of soil under this crop.

Should potato disease be common in the district, the garden-worker should not wait for signs of its appearance, but should apply Bordeaux mixture in good time, taking all the precautions given under this heading in the chapter on plant diseases (p. 276). Upon no account should he pull off the stems and leaves of diseased plants. The result will be that starch-formation is interrupted, growth of the tuber ceases, the starch already contained in the tuber is not matured, and there is loss in both size and flavour.

23. **Radishes.**—Keep the soil as cool and moist as possible by abundant waterings and by maintaining a soil-mulch. Use the roots when they are still growing and do not allow them to get to a great size. Thin-out by using the largest, 3 inches being quite sufficient for a final thinning.

Radishes are only a short period in the ground, in fact but about five weeks, and sharp, continuous growth from germination to harvest is required if the roots are to be of the best flavour. The soil must therefore be cool and moist, so that a surface-mulch to conserve moisture is absolutely necessary. The plant is shallow-rooted, and therefore, lest the moisture-supply in the surface should run short, copious waterings should be given, and a mulch of soil made as soon after as possible. The roots taste best when small and crisp, for as they mature, and growth ceases, they become stringy and hollow.

24. **Rhubarb.**—During the first season pull no leaves from newly-planted crowns. In pulling stalks from established clumps, take great care that no undeveloped buds are removed. Pull the largest and strongest stalks first, but in every case leave a few of these on the plant. Do not remove leaves late in the season from plants which are to bear crops in the following year. Apply liquid manure steadily during the period of growth.

Cover over a few crowns with boxes and "long" manure before winter, to produce an early supply.

Newly-planted crowns should have none of their leaves pulled during the first season, for it is necessary that food be manufactured in the leaves and stored up in the root-stock if a good crop is to result in the following year. In pulling stalks the worker should take care that he does not remove a bud which has not yet grown into leaves, or many stalks may be lost. The plant must not be denuded of all its largest leaves, or but small quantities of food will be passed downwards and stored up for the following year's growth. The rhubarb crop of any year depends largely upon the leaf-development of the plant, after pulling of stalks has ceased the season before. If stalks are pulled late in the season, little or no food will be stored in the root-stock for the following year's growth.

25. **Salsify.**—Maintain a surface-mulch. Thin-out to 9 inches or so. Leave in the ground during winter, and cover with leaves before the frosts come on.

This crop presents little difficulty in cultivation. As the plant is deep-rooted, a soil-mulch will ensure a sufficiency of moisture.

26. **Shallots.**—Firm the soil and stir the surface alternately throughout the period of growth. Loosen the soil from around the bulbs when they begin to swell, taking care that the tops are not torn during the operation. Bend over the tops should the harvest seem to be delayed. Harvest about the end of July. Treat exactly as for onions with regard to lifting and storing. Select the roundest and firmest for planting in the following year.

Shallots have few enemies, and with continued firming of the soil to produce stocky growth, and surface stirring to conserve moisture, a satisfactory crop should be had. To allow the bulbs freedom to swell, the earth should be removed from around the plants just when the bulbs begin to put on girth.

27. **Spinach.**—Thin-out to 3 to 6 inches apart. Many growers do not thin at all. Give abundant supplies of water and maintain a soil-mulch. Apply liquid manure once per week throughout growth, with occasional top-dressings of nitrate of soda.

If thick sowing be not practised, thinning-out is hardly necessary. Since the crop is grown for its leaves, as are lettuce, somewhat similar treatment suits. Cool, moist ground is maintained by copious waterings and surface-stirring. As leaf-formation is the chief business of the plant, nitrate of soda as a top-dressing and applications of liquid manure are beneficial.

28. **Turnips.**—Two distinct croppings are included under this heading—the summer and the late-autumn and winter crops. It is the former which gives more trouble.

Keep the soil for the summer crop as cool and moist as possible by occasional soakings of water and stirring of the surface soil. Thin twice, first to 3 inches and later to 6 inches apart. Sprinkle the leaves when they are wet, with wood ash and soot; and to fight the flea beetle apply a slight top-dressing of nitrate of soda first when the plants are in the seed-leaf stage and again when they are singled out. Continue stirring the soil throughout the period of growth.

For a supply in late autumn, sow early in September, or preferably in August if possible. White-fleshed varieties may safely be sown now. For winter supply, swedes are best. Sow at the same time as those for summer use. Allow these to remain in the soil until they are wanted.

Cool, moist soil is essential for the right growth of turnips which are to form the summer supply. Watering and the steady use of the hoe to maintain a soil-mulch are therefore absolutely necessary, otherwise, should a period of drought come, growth in the plant ceases, the pulpy ball becomes woody and stringy, and the plant sets itself to produce flowers and seeds. This is called "bolting." Some varieties, the white-fleshed kinds in particular, are more prone to bolt than others.

Six inches is sufficient distance between the plants in the garden. Large balls are not desired. These are apt to be stringy and hot to the taste, and the best turnips for table purposes are those which have been grown steadily from the start till the time they are the size of a tennis ball.

If seeds be sown in August or early September for a late-autumn supply, there is little danger of hot, dry weather, and bolting is not to be feared. White-fleshed varieties, therefore, may be safely sown and treated as above. Swedes, as their period of growth is longer and the size to which they are grown is larger, should be thinned-out to at least nine inches apart. They attain their best when they have received a good touch of frost, so they may be left in the soil until they are required.

CORRELATED EXERCISES.

1. Account for the wonderful inherent fertility of virgin soils, *e.g.* the prairie lands of North America, the black soil lands of Russia, etc. How do you explain the former tendency of the American farmer "to move westward" after a certain number of years?

2. Name some wild plants which are usually found growing in the following types of soil: sand, clay, bog, cultivated ground.

3. In certain parts of the Continent where vines are grown on hill sides, flat stones are commonly laid over the soil in the vineyards. What is the purpose of this? Explain the effect.

4. In summer, take the temperature of the soil in a pasture field and the temperature of a piece upon which nothing grows. Account for the difference.

5. The top of a rain gauge is usually 5 inches in diameter. On October 5th, 1911, there were 9·8 cubic inches of rainfall in the gauge. How many inches of rainfall does this represent? How many gallons per acre?

6. Find the average rainfall per day for your district. How many gallons per day does this represent upon a garden plot 30 feet by 9 feet?

7. Some seeds sown in late autumn, or in November, fail to germinate. Describe what happens to them.

8. How is it that watering plants on a still evening in May helps to prevent their being hurt by frost?

9. Why should stalks of rhubarb not be pulled late in the season from stocks which are to furnish the following year's supply?

10. What is meant by a "weed of cultivation"? Distinguish between these weeds and the common wild flowers of the hedgerow.

11. Account for the fact that cabbage stalks from which the heads have been cut in spring usually develop three or four new smaller heads during summer.

12. Describe in detail the benefits resulting from the earthing-up of potatoes. Are cabbages earthed-up for the same purpose?

13. What exactly happens in spring when rhubarb crowns are covered over with boxes before winter comes on?

14. In irrigated Southern California both garden and field crops may be sown at any season except during two months of the year, and be brought to maturity. In Algeria three successive crops of potatoes may be taken off one piece of irrigated land in one season. Account for the fact that these things cannot be done in Britain.

CHAPTER VIII.

SPECIAL PLOTS.

1. Experimental plot.—Choose which of the following types of experiment you intend to work during the year. Make a sketch plan of the experimental plot arranged to suit it and then draw the plan to scale.

Measure and peg off the plots; and plant or sow according to plan and to season. Give the plot due attention, clearing off weeds, tying up plants, etc., throughout the period of growth. Plants must be examined regularly and their progress noted. Any signs of disease or insect attack must be dealt with as soon as noticed.

TYPES OF EXPERIMENT.

I. To study the method of plant growth.

(*a*) *Tap-rooted plants.*—Beet, carrot, parsnip, turnip, radish.

(*b*) *Underground stems, etc.*—Potato, dahlia, peony, Solomon's seal, early orchis, lesser celandine.

(*c*) *Climbing plants.*—Ivy, hop, scarlet runner, nasturtium, clematis, fumitory, pea, Virginia creeper.

(*d*) *Pollination.*

- (α) By wind.—Hop, plantain.
- (β) By animals (chiefly insect). (1) By night.—Catchfly. (2) By day:
  - (i.) Pollen only.—Anemone, clematis.
  - (ii.) Honey.—(1) Exposed—Rose, buttercup, grass of Parnassus; (2) Concealed—Figwort (for short proboscis), foxglove (for long proboscis), orchis, viola, gentian, campion, monkshood.

(*e*) *Seed dispersal.*

- (i.) By scattering.—Poppy, antirrhinum, balsam.
- (ii.) By wind.—Thistle, willowherb.
- (iii.) By animals :
    - (1) By eating.—Snowberry.
    - (2) By adhesion.—Avens, medick, goose-grass.

Several of the above plants will serve for observation work in connection with transpiration, pressure of ascending sap, adaptation, etc.

Tap roots.—Quite a number of plants store up starchy matters in some part of their structure. This stored food will provide nourishment for the growing plant in the early part of the following year, when the warmth of the soil is not sufficiently strong to permit of the formation of nitrates and consequent feeding of the plant.

The tap-rooted plants are a good example of this. They store up food during their first season of growth, and use it in the following year, so as to obtain a good start for the formation of flowers and seed. Even should the crown of the plant, *i.e.* the upper part, leaves, etc., be cut off by accident or design, the tap root usually has the power to develop adventitious buds and continue growth in the following year. This is especially marked in a weed like the dock. No amount of cutting away of leaves is sufficient to kill this plant. Buds quickly develop and the plant continues to grow. To eradicate it thoroughly the whole, or almost the whole, of the root must be dug up.

It is common to see parsnips and beet whose roots, instead of being in one tapering piece, branch out into several, in other words "become fangy." This reduces the cooking value of the plant, and should be guarded against so far as possible. The branching is the result of the plant's attempt to absorb food-material which is situated other than directly beside it, and is easily caused by the fresh application of farmyard manure to the carrot or parsnip bed. The danger of doing this may be shown in this plot; half of the row of tap roots receiving farmyard manure during the first year of growth and half receiving none. None of these should be pulled up at the end of their first year's growth, but should be allowed to flower and fruit in the following year. Obviously none of the tap roots in the garden-plots should be allowed to run to seed.

The value of having a deeply dug bed for such crops may be seen by carefully digging round a strong parsnip plant towards the end of the season, following out the root to its utmost extremity, and measuring the depth to which it descends.

2. Compare the root of parsnip with roots of the black currant, whose absorbing roots lie just under the surface of the soil in many cases. For your own benefit, examine as many plants as you can, and draw up a list of deep-rooted and shallow-rooted plants.

Underground stems, etc.—The potato is taken as typical of the plants studied under this heading, and the following list of questions which can be answered only by practical examination of the tuber at the several stages—unsprouted, sprouted, and growing—may with certain modifications be applied to most of the plants under this heading.

3. (i.) **Examination of unsprouted tuber.**—Obtain a kidney-shaped tuber with the "eyes" well marked; place it in position so that the "eyebrows" are underneath the hollow containing the "eye," and make a drawing of the potato.

Can you find any regular sequence in the position of the "eyes"? Stick a pin into the hollow of each eye, tie a thread to the lowermost pin, and pass it round the tuber to the next pin in position. Wind it round this and pass on to the next, continuing until the end of the potato is reached. Do you see any sequence now? Examine the position of the leaves on the stem of a growing potato. Do you notice any similarity of sequence between the "eyes" and the leaves?

On which part of the tuber are the eyes so massed as apparently to depart from this order?

Try to distinguish the mark on the base of the tuber where it was joined to the parent plant by means of its stalk.

(ii.) **Examination of sprouted tuber.**—Note how many of the "eyes" have sprouted. Which has developed most strongly?

The hollow called the "eye," then, is in reality the position of a bud which may grow out into stem and leaf, and as a bud always develops "in the axil of a leaf," the "eyebrow" is really the mark of an undeveloped leaf. So the tuber has leaves growing from it, and it bears buds which grow out into stem and leaf. Can it therefore be a root? What part of the plant must it be?

What has caused this stem to assume so strange a shape?

Count the number of buds which have developed. If each grows, how many potato plants might be had from the tuber? Why do you consider it unsafe to cut the potato into this number of parts and plant each separately?

(iii.) **Examination of a growing potato plant** (Fig. 56). From which parts do the roots spring?

Does any part of the tuber show any signs of life save the buds?

Note the stalks bearing young potatoes. From what point in the plant do they grow? Would it be correct to say "from the axil of a leaf"? Can you distinguish signs of the leaf in any case?

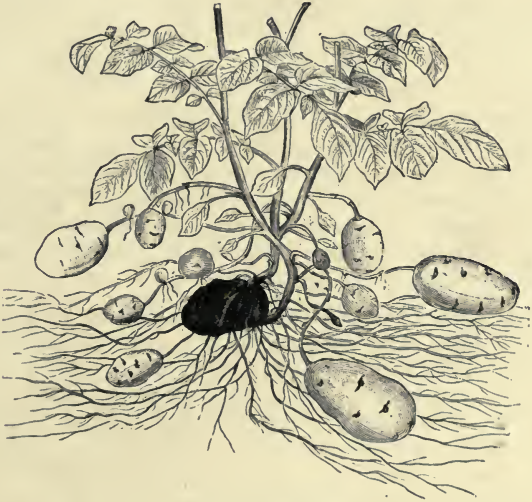


FIG. 56.—Potato plant.

Do the tubers grow from above, among, or below the roots?

Are the tubers in any case produced on the roots? Why?

At what point in the life of the plant do the tubers begin to form?

Does one stalk ever bear more than one tuber?

Measure the length and diameter of the stalk immediately the tuber has begun to form, and find whether the stalk increases in any way after this.

Leave one potato plant unearthed, earth-up one slightly, pile earth high up to another. Has earthing-up anything to do with the number of tubers produced? Explain how this is so. What happens to side-stems which are not kept in darkness by being earthed-up?

4. **Climbing plants.**—Examine each climbing plant and find out by what method it climbs: by leaves, by tendrils, by stems, etc. Does each have any influence upon the plant or object to which it climbs, *i.e.* does it extract food from it, crush it so as to injure its growth, or otherwise affect it?

Is each plant haphazard in its method of climbing, *i.e.* does it twist its stem or leaves or tendrils, now in one direction, now in another?

Find by examination and calculation whether all movements proceed with clockwork steadiness, or are spasmodic. This can be done by training a scarlet runner to a bamboo cane, and noting the length of time taken by the growing point to make one revolution.

5. **Pollination.**—The importance and general meaning of cross-pollination will have been explained in the past nature-study work. Attempt to find the result of no pollination. Cover a flower with a paper bag immediately it begins to form, so that pollen-bearing animals may be shut out. Cut off the anthers as they appear, taking care that they do not ripen first, and examine for seed later. What conclusions do you draw from your work?

6. **Seed dispersal.**—The question of seed dispersal is of chief importance in connection with weeds, and too great care can hardly be given to this part of the work if weeds are to be kept within bounds.

Why do not plants allow their seeds to drop just where each plant grows, and there to develop? Note the special method adopted by each weed to ensure the scattering of its seeds. One carelessly kept plot in the garden may mean extra work in a dozen plots next year, owing to the scattering of seeds by the plants, the wind, or by animals. The same is true if weeds which bear seeds that are carried by the wind are allowed to flourish in the vicinity of the garden, even though outside the actual garden ground.

II. To study the most favourable physical conditions for growth.

(*a*) Choose potatoes of the same variety, of equal weight and similar shape. Plant:

(1) A row of whole tubers.
(2) A row of half tubers.

(3) A row of whole tubers, breaking off all the stems save two, as they appear above ground. Tubers of 1, 2, and 3 should be all at the same depth and same distance apart.

(4) Five rows of whole tubers set 6, 9, 12, 15, and 18 inches apart in each row respectively, all at the same depth.

(5) Three rows of whole tubers 4, 8, and 12 inches deep in each row respectively, at equal distances apart.

(6) A row of splits, *i.e.* potatoes cut into pieces (p. 83), with cut surface in contact with the farmyard manure used.

(7) A row of splits with earth between the cut surface and the farmyard manure used, splits of 6 and 7 being at same depth and equal distances apart.

(8) A row of whole tubers which have been previously well sprouted.

(9) A row of whole tubers which have been previously badly sprouted in darkness and have weak growths.

(10) A row of whole tubers (unsprouted), which are not earthed up, tubers of 8, 9, and 10 being all at same depth and at equal distances apart.

(11) A series of rows of cabbages, or better still, in each of the following two cases, small plots 6 to 8 feet square, plants being in each row or plot, 6, 9, 12, 15, and 18 inches apart respectively, giving them equal quantities of water throughout the season.

(12) A series of rows or plots of carrots, or turnips, or parsnips, etc., thinning-out to a distance of 2, 4, 6, 8, and 10 inches respectively in each row.

(13) A row of chrysanthemums and one of rose bushes, one half of each row to have buds thinned-out, and the other not.

(14) A row of cuttings of gooseberry and currant bushes, of apple and pear trees; cut the bases in different places, pick off the lower buds in some cases, in others do not.

The above plants should also be used in working out the connection between the area of leafage and the amount of water needed; the shape of the plant and the distance needed between the rows and between the plants; the supply of light and air and the health of the plant, etc.

Record in each case the date of planting, date of harvesting, the weight and condition of the crop.

Practical Conclusions.—A dozen whole tubers will be found, as a rule, to yield a better crop than the same number of splits; while if but two stems be allowed to come, the tubers are larger and more finely formed.

One experience of close growing is usually sufficient to convince any garden-worker of the importance of giving plenty of room between plants. Potatoes with long, unhealthy stems, and small, unprofitable tubers; cabbages "leggy" and of poor heart; carrots run to leaf, thin, and malformed; all especially susceptible to disease and liable to be blown down by a slight breeze—are some of the results of close planting. The plants are fighting for food-material, moisture, air, and light; they expend energy in the development of much leafage, stem, and many rootlets in their search for these; and the result is that the very parts which have been much developed by cultivation have no opportunity of receiving the necessary amount of food.

The practice, so common in many farms and gardens, of planting potato splits in contact with farmyard manure is a very potent cause of much of the scab which ruins the appearance of the tubers, being at the same time largely responsible for blank spaces in the row, as the tubers are apt to rot off.

It is extremely important that early potatoes be sprouted previous to being planted; the difference in date of harvest between sprouted and unsprouted tubers is strongly marked, while the effect at harvest may run to a 20 per cent. increase in weight. The folly of allowing potatoes to sprout without a sufficiency of light and air is evidenced by long, white, soft, and sickly growths. These are signs of wasted food substance, and when planting time comes many sprouts are certain to be broken off in the operation, and the potato rendered "blind."

The importance of earthing-up potato plants will be seen when the weight of row No. 10 is compared with that of No. 1. Each stem on which the tubers develop arises in the axil of a leaf (Fig. 56). If this point be under ground, *i.e.* shut off from light, the stem stores up starchy materials at its extreme end where the tuber forms; but if the axil of the leaf be above ground, then the stem is no longer shut off from light; it assumes all the characteristics of an above-ground stem, develops leaves and possibly flowers, and is lost to the gardener so far as potato growing is concerned.

Overcrowding, even in the case of blooms, causes poor results.

Unless a rose bush be disbudded, the only blooms to be had are undersized, ill-formed, and often green-hearted. The same is true of chrysanthemums and many other plants. The gardener must, within reason, grow for quality more than quantity; if rosebuds are fighting for food-material, moisture, and light, few beautiful roses will be cut. On the other hand, drastic disbudding to one central bud in each case often causes malformation, and certainly results in a bush being beautiful for but one week or so, as all the roses are apt to come into bloom at the same time. Disbudding is certainly necessary, but over-disbudding is unwise.

The broad leaves of cabbages indicate much transpiration and the absorption of a large amount of nitrogen from the soil, and therefore the need of much watering and a large application of nitrogenous manures. On the other hand, the feathery leaves of the carrot and the undesirability of this part of the plant becoming over-developed at the expense of the tap root, at once suggest totally different treatment. Even from a crop of cabbages much may be learnt; "leggy," unhealthy-looking plants being the result of leaving them too long in the seed-bed; while later it is found that the distance between the plants depends entirely upon the method of growth which the cabbage adopts, Ellam's Early needing but 12 inches of space, while larger growing sorts need anything up to 2 feet. No attempt is made here to be exhaustive, as almost all the plants grown in the plot should be similarly examined; all that is intended is to indicate the lines upon which the student should proceed in his observations.

7. If ground be available, a series of plots may be laid down for many different problems: to find out at what depths different seeds should be sown; the effect of using large seeds as against small; and so on. Each plot should be labelled, progress noted, and the produce weighed and recorded at harvest time.

III. To study the most favourable manurial conditions for growth.

The quantity of fertilisers given in each case is per acre, and the weight necessary for each plot must be calculated carefully.

(i.) Potatoes.

Plot 1. No manure.
„ 2. Complete manure 2 cwt. sulphate of ammonia.
6 „ superphosphate, 38%.
2 „ sulphate of potash.
„ 3. Same as 2, but *no potash.*
„ 4. Same as 2, but *no superphosphate.*
„ 5. Same as 2, but *no sulphate of ammonia.*
„ 6. 2 cwt. sulphate of ammonia.
6 „ superphosphate, 38%.
8 „ kainit.

8 cwt. of kainit supplies the same amount of potash as 2 cwt. of sulphate of potash. In the result, note whether there be any difference in the eating quality, in addition to the weight of the potatoes, from plots 2 and 6.

(ii.) Cabbages.

Plot 1. No manure.
„ 2. Complete manure 1½ cwt. nitrate of soda.
6 „ superphosphate.
3 „ potash salts.
„ 3. Same as 2, but *no potash salts.*
„ 4. Same as 2, but 4 *cwt. nitrate of soda.*
„ 5. Same as 2, but 6 *cwt. nitrate of soda.*
„ 6. Same as 2, but *no nitrate of soda.*

All supplied with equal amounts of water.

(iii.) Turnips.

Plot 1. No manure.
„ 2. Complete manure 1½ cwt. sulphate of ammonia.
6 „ superphosphate.
2½ „ potash salts.
„ 3. Same as 2, but *no potash salts.*
„ 4. Same as 2, but *no superphosphate.*
„ 5. Same as 2, but *no sulphate of ammonia.*

Note whether turnips on plot 4 are later in being ready for singling than those in the other manured plots.

(iv.) Onions.

Plot 1. No manure.
„ 2. Complete manure 4 cwt. nitrate of soda.
5 „ superphosphate.
2 „ sulphate of potash.
„ 3. Same as 2, but *no potash.*

(v.) Peas.

Plot 1. No manure.
" 2. Complete manure { 1 cwt. sulphate of ammonia.
5 " superphosphate.
3 " potash salts.
Peas sown 6 inches apart.
" 3. Same as 2, but *no sulphate of ammonia.*
" 4. Same as 2, but peas sown thickly.

Note any difference in cooking quality between peas from plots 2 and 3.

(vi.) Leeks.

Plot 1. No manure.
" 2. Complete manure { 6 cwt. superphosphate.
4 " potash salts.
1 " nitrate of soda.
" 3. Same as 2, but *no nitrate of soda.*

8. Laying off the plots.—While no difficulty will be experienced in laying off the plots for experiments under heads I. and II., those under III. need careful management. The plots should be pegged off so as to allow a path at least 12 inches wide between them. This is necessary if the manurial conditions of each plot are to be kept as originally intended. Where the plots are small, being but a few square feet each, planks, at least 12 inches wide, may be sunk in the earth, allowing a couple of inches to project above the ground line, and these prove quite efficient divisions between the plots. The main objection to this

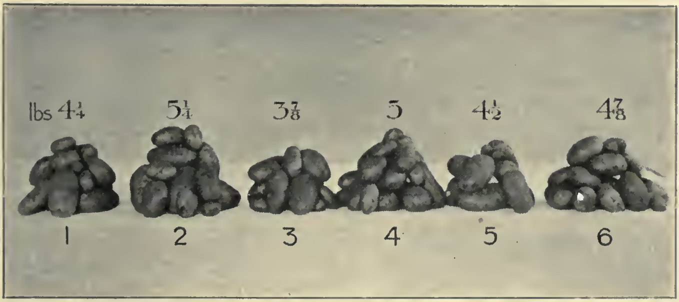


Photo. Mr H James

FIG. 57.—Potatoes treated as described on p. 144.
Results of manurial experiments as above, at Gordon Schools, Huntly.

method is the expense of the wood; but if used wood be bought cheap, and well tarred, it will suit the purpose admirably. Find the area of each plot, and calculate the amount in ounces of each fertiliser to be applied. The result should be worked out to the nearest workable fraction of an ounce, the amount weighed, and the manure worked into the earth previous to the setting in of the crops, except in the case of nitrate of soda, which is applied at intervals as a top-dressing.

Carefully label each plot according to the plan drawn out, and give great care to the detection and prevention of disease. A whole year's work in experiment is often ruined by allowing an attack of disease to proceed too far before a remedy is applied.

Possibilities of error.—In attempting manurial experiments the school garden-worker labours under the difficulty that his plots are so small that results can hardly be accepted as conclusive. For example, the difference in constitution of one potato may cause it to produce a greater crop than another of the same size and variety; or a cabbage may have more vitality than one in the neighbouring plot—each factor helping to increase the possibility of error in the result. But though each plot be so small as to include but six plants of each crop experimented with, certain lessons may be learnt.

Conclusions particular, not general.—Too often the gardener accepts the conclusion of an expert who has experimented with soil quite different from that of the garden in question, and applies manures accordingly. Even the field across the garden-fence may not have the same manurial requirements as the garden, in fact, will certainly not, if the latter has been under intensive cultivation for some years. The garden-worker's business is to find out by experiment what artificial manures cause his garden to give the greatest response in the way of crops, and having discovered this, to manure accordingly. He is not attempting to find whether potatoes generally respond to an application of potash, but whether in his garden the crop of potatoes obtained by the application of this manure justifies the expense. He is, indeed, not attempting to establish general principles (these have been worked out already), but is experimenting to find what manure applied to a certain crop in his garden gives a return which compensates for the expense. And he experiments, not for the love of experimenting, but with a practical end in view, viz. the correct manuring of each crop in his garden.

9. **Seed-bed.**—The best spot to choose for a seed-bed is a small, out-of-the-way corner, sheltered from the wind and protected somewhat from the strong rays of the sun. Much ground is not as a rule needed, but it should have a few barrowfuls of sharp sand and well-rotted manure worked into it, if the best results are to be obtained. Deep digging is of course essential, as is also the careful eradication of weeds. A thick-set, low hedge of gorse branches renewed each year should surround it, the gorse being buried for some six inches in the earth and rising about the same height above it. In this way mice and other small animals having a fondness for tender young leaves are shut out, while the danger from moles is considerably lessened.

Biennials, such as wallflowers, sweet-williams, Canterbury bells, etc., will be grown here each year; and each year also a few kinds of herbaceous plants will be raised, three or four species being a sufficient crop at a time. A few square feet each will be sufficient space for the number of cabbages, Brussels sprouts, broccoli, etc., needed for the school garden; and few other plants need be considered.

Botanical plot.—No garden-lover is justified in being absolutely ignorant of wild flowers, even though he does treat them all as weeds when they suddenly make their appearance in his pet bulb plot. Almost all our finest flowers of the garden have at one time been what is termed wild, and have been cultivated to their present state of beauty from the florist's point of view by a process of selection, some being chosen for their beauty of bloom, some for their foliage, and others for their scent. Gradually, by the elimination of those which showed the required characteristic to a smaller degree, and by the selection of seed from the best blooming or scenting specimens, the plant was brought to its present perfection. But that these are not the natural conditions of the plants is shown by the fact that if left alone they are apt to revert to type, in other words to assume the characteristics of the wild plant again. Fig. 58 shows a branch of a variegated maple tree, the right-hand side of the spray bearing leaves which are small and variegated and the left-hand bearing leaves large and of the natural green. Owing to lack of careful cultivation the tree is reverting to the broad-leaved, green type of plant. The same tendency can be found in many garden plants.

It is of interest to the gardener, therefore, to examine and know the wild relations of the plants upon which he lays so much store; and if he makes a collection by digging them up and planting them in a special place in the garden, each one will become a friend in which he takes an interest. Further, by having these plants regularly before him he has greater opportunity of becoming acquainted with their characteristics and method of growth, than if he sees them only in his country walks. But wild flowers have an interest other than their connection with those which are cultivated. Garden plants have not only had some special point of their structure developed to what is considered perfection, but in the cultivation certain other characteristics of the plant have had to be sacrificed so as to permit of this development. For example, the wild cabbage under the process of selection lost its tendency to develop many small malformed heads ere it emerged from culture as our common garden cabbage; and the wild carrot had to restrict to a very great extent its tendency to run to stem and leaf, in order

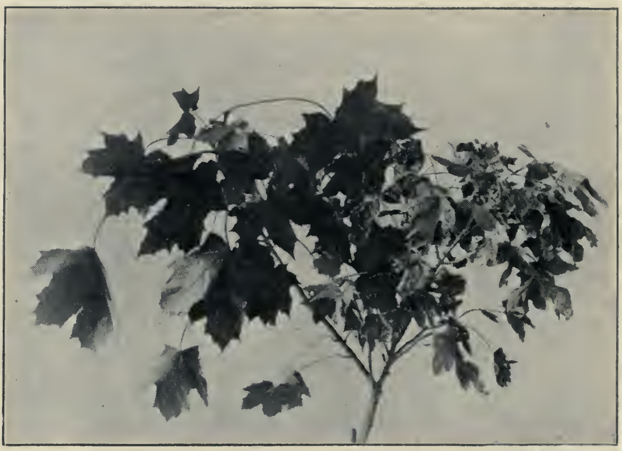


Photo Mr H James

FIG. 58.—Branch of a variegated maple tree which is reverting to type.

that the thick, tap-rooted garden vegetable might be produced. So that it is evident that much about plant life and growth is to be learned from wild plants which is not very obvious in garden varieties.

Botanical studies.—But it is in connection with the systematic study of botany that the botanical plot is of most importance. The plants are ready to hand at any time, and what is an even more evident advantage is the fact that they are arranged systematically, so that members of the same family can be seen at a glance. By no other means are the characteristics of the various families so easily impressed upon the mind, and, in addition, the student has but to turn to his own vegetable plot to seek for cultivated relations.

It is, of course, impossible to include representatives of all the British families in a school botanical plot, so some selection must be made. The following families have been found to form a good selection: Buttercup, Poppy, Viola, Wallflower, Pink, Geranium, Pea, Rose, "Star," Daisy, Primrose, Borage, Speedwell, Dead-nettle, Orchis, Lily, Sedge, Rush, Grass. Reference to any good flora will enable the student to choose the most suitable members of these families.

10. Herbaceous border.—The filling up of this plot should be gradual, and the selection of the plants which are to find a place here is a matter which should receive great attention. There should be no promiscuous sticking-in of any odd piece of plant which, perhaps, has been thrown out of some garden as useless; and the unorderly dotting about of snippety bits of roots should be considered an offence against good taste. No part of the garden suffers more from careless arrangement than this, while few plots will so well repay as much thought as the garden-worker cares to bestow upon it.

The herbaceous border shows to greatest effect when it lies next the outside edge of the garden. When placed there it comes as a final mass of colouring, marking a definite close to the display of the garden, and acts as an effective background to the whole. In many cases, however, especially in the school garden, where the division of the ground into plots of equal size departs very considerably from the ordinary arrangement of a cottage garden, the necessity of such a plot-system precludes any possibility of the herbaceous border being placed along the edge of the ground, owing to the shape of the piece of land at disposal. It may thus be necessary to have the plot for herbaceous plants running along the ground in a central position. Each of these conditions needs special arrangement of plants if the result is to be effective.

The first principle, which is so obvious as to require little comment, is that taller-growing plants should not hide those of less strong development. To bring this about, the former should take a rear place in the border which is backed by a garden-fence, while in the plot which has a walk on either side of it they must be planted more or less in the centre.

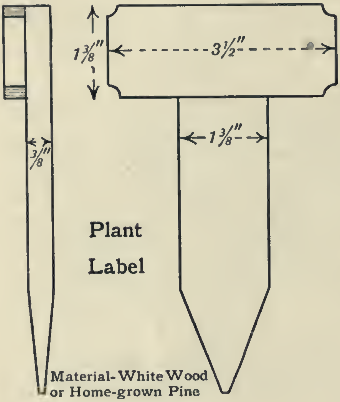
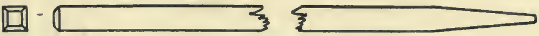


Fig. 59.

This, however, requires some modification. While restfulness is a most desirable quality in a flower garden, it need not necessarily be accompanied by that dull uniformity which is apt to be the result of the above arrangement, unless here and there a taller-growing form encroaches upon the territory of the more low-growing, and breaks the general sameness. This introduces a new element, *i.e.* the necessity of producing variety by departing occasionally from the above-mentioned treatment, by allowing a bold mass of taller flowers here and there to jut outwards into the sea of more low-growing plants, thus breaking their uniformity and by contrast adding to their beauty.

This suggestion of itself presupposes that the plants are set out in masses, not as individual specimens. The herbaceous border is effective as a mass. Beauty of individual bloom we seek where plants are grown isolated. The latter are examined at close quarters, the former are admired at some little distance. Thus clumps of plants of the same variety are most effective in the herbaceous border, and if the effect is to be satisfactory these clumps must not be regular in shape, but, as suggested above, should break away here and there, forcing their way out into the midst of the low-growing plants around them.

11. Filling up the ground for a herbaceous plot.—Obtain such plants as you can, taking care to order clumps of a few, rather than sprigs of a large number. Insist upon each being correctly named. Draw a plan of the ground at your disposal. Arrange upon the plan the names of those plants you have got, in accordance with the above advice. Too much space between the clumps is better than too little. Plant out in November and label each distinctly. Fill up the remainder of this bed for the first year with biennials and annuals. Later, by the omission of some annuals, room should be made for new herbaceous plants as they are received.



Plant Support ⅝″ square – length as required
Material- White Wood or Home-grown Pine

FIG. 60.

Weed carefully and continually, and maintain a soil-mulch, or otherwise many moulds will find a congenial home under the dense foliage, and rob the plants of food-materials. Thin-out annuals, so that only strong, healthy plants are allowed to develop. Support where necessary and cut blooms regularly.

HARDY PERENNIALS.

(Plants which bloom only during the period of the summer vacation have been omitted from this list. The time of flowering will of course vary somewhat with locality.)

Popular name.	Botanical name.	Colour.	Height in feet.	Season of blooming.
Thrift or sea pink	Armeria maritima	rose	½	June
Daisy	Bellis perennis	all colours	½	April and May
Gentianella	Gentiana acaulis	blue	½	May
Gromwell	Lithospermum prostratum,	blue	½	May and June
Evergreen candytuft	Iberis	white	½–1	April and May
Forget-me-not	Myosotis dissitiflora	blue	1	May and June

HARDY PERENNIALS—*Continued.*

Popular name.	Botanical name.	Colour.	Height in feet.	Season of blooming.
Foam flower	Tiarella cordifolia	white	1	May and June
Scarlet avens	Geum Heldreichii	orange	1–2	May and June
Lenten rose	Helleborus orientalis	various	1–2	Feb. and March
Alum root	Heuchera	red	1–2	May and June
Speedwell	Veronica gentianoides	blue	1–2	May and June
Japanese stonecrop	Sedum spectabile	rose	1½	Sept.
Christmas rose	Helleborus niger	white	1½	Nov. to Jan.
Pyrethrum	Pyrethrum roseum	various	1–2½	May and June
Columbine	Aquilegia	blue, yellow, and white	1–2½	May and June
Corfu lily	Funkia subcordata	white	2	August
Groundsel	Senecio pulcher	purple	2½	Sept.
Japanese anemone	Anemone Japonica	white and red	2½	Aug. and Sept.
Shell flower	Chelone glabra	pink	2–3	August
Campion	Lychnis chalcedonica	scarlet	2–3	June and July
Michaelmas daisy	Aster (perennial)	all colours	2–4	Sept. and Oct.
Garden chrysanthemum	Chrysanthemum	all colours	2–4	Sept. and Oct.
Larkspur	Delphinium	various	2–4	June and July
Black snakeroot	Cimicifuga racemosa	white	2–4	Aug. and Sept.
Chalk plant	Gypsophila paniculata	white	3	July
Giant asphodel	Asphodelus luteus	yellow	3	April and May
Flea bane	Erigeron speciosus	purple	3	August
Scarlet lobelia	Lobelia cardinalis	scarlet	3	Aug. and Sept.
Lupins	Lupinus	white, pink, blue, purple	3	June
Oriental poppy	Papaver orientale	scarlet	3	June

HARDY PERENNIALS—*Continued.*

Popular name.	Botanical name.	Colour.	Height in feet.	Season of blooming.
Late phlox	Phlox (perennial)	various	3	Aug. and Sept.
Purple cone flower	Rudbeckia purpurea	purple	3	Sept.
Double meadow sweet	Spiraea ulmaria	white	3	June and July
Globe flower	Trollius	yellow	3	May and June
Italian alkanet	Anchusa italica	blue	3	June and July
Paeony	Pæonia	various	3	June and July
Blazing star	Liatris pycnostachya	purple	3–4	Aug. and Sept.
Goat's rue	Galega officinalis	white	3–4	June
Tree lupin	Lupinus aboreus	white and yellow	4	June and July
Sneezewort	Helenium autumnale	yellow	4–5	Sept.
Torch lily	Kniphofia Tuckii	red	4–5	June
Loosestrife	Lythrum salicaria	rose	4–5	June
Sunflower	Helianthus (perennial)	yellow	4–6	Aug. and Sept.
False starwort	Boltonia asteroides	pink	5	Sept.
Oriental seakale	Crambe cordifolia	white	5	June and July
Golden rod	Solidago Shortii	yellow	5	Sept.
Plume poppy	Bocconia cordata	cream	5–6	June and July.
Cone flower	Rudbeckia (Golden glow)	yellow	5–6	Sept. and Oct.
Everlasting pea	Lathyrus latifolius	purple	6	July and Aug.

Manuring.—Naturally it is impossible to continue to grow plants year after year on the same soil without impairing the fertility of the land, unless the food-materials be renewed in some form. To dig-in farmyard manure is well nigh impossible, as the entire surface soil to the depth of 6 inches or so soon becomes a network of fibrous roots, even the space between the plants being thus occupied. The digging-in of farmyard manure would so injure these roots that the plants would suffer badly, so that manuring must be done by surface mulching. A good layer of well decayed farmyard manure laid on in early winter is of much use in this connection. An inch-deep covering of leaf-mould, wood ash, and soot mixed well together, laid on and raked in in early spring, if given in addition to the above, will keep the soil in good condition.

HARDY ANNUALS.

Name.	Height.	Colour.
Alyssum, sweet	4 to 6 in.	white
Alyssum, compactum	9 in.	white
Candytuft	6 to 12 in.	various
Calandrinia speciosa	6 in.	rosy-crimson
Crysanthemum (annual)	9 in. to 2 ft.	various
(Morning Star and Evening Star are	the best)	
Clarkia	2 ft.	various
Cornflower	3 ft.	blue, white, and pink
Coreopsis (various)	1 to 2 ft.	various
Eschscholtzia	1 ft.	various
Flax	1 to 1½ ft.	scarlet and rose
Gaillardia	2 to 3 ft.	various
Godetia	6 in. to 2 ft.	various
Gypsophila elegans	1½ ft.	white
Helichrysum (everlasting)	3 ft.	various
Kaulfussia amelloides	6 in.	blue
Larkspur	1 to 3 ft.	blue and carmine
Leptosiphon (dwarf)	3 in.	yellow, rose, and carmine
Love-in-a-mist	2 to 3 ft.	crimson, scarlet
Lupin	1 to 3 ft.	scarlet, blue, yellow, and white
Mignonette	1 ft.	yellow
Nasturtium (Tom Thumb)	1 ft.	from dark crimson to pearl
Nasturtium, tall	5 to 10 ft.	from dark crimson to pearl
Nemophila	6 in.	blue and white
Poppy (Shirley)	1 to 2 ft.	many shades
Silene	4 in.	white and rose
Saponaria	6 in.	rosy scarlet
Sunflower	4 to 8 ft.	yellow
Sweet peas	3 to 10 ft.	various
Sweet scabious	3 ft.	white, lilac, and crimson
Sweet Sultan	1½ to 2 ft.	white, yellow, and mauve
Sweet-william (annual)	1 ft.	various
Venus' looking-glass	9 in.	white and blue
Virginian stock	6 to 9 in.	white and red

Annuals and biennials.—If the herbaceous border be of considerable size, it will be impossible to have it filled up with suitable perennials at the outset. This can be partly remedied by the use of annuals and biennials, with precautions as regards room as already given (p. 88). In fact, in every school garden a piece of ground should be set aside in the herbaceous border or elsewhere where masses of biennials like sweet-william may be grown. A mass of these, arranged according to colour, can be made very effective indeed.

As good a time as any for sowing all the above seeds is the last week of March; but no garden-worker can have failed to notice, for example, that a seedling of *Nemophila insignis* which has been naturally sown in the previous autumn in some out-of-the-way corner, often successfully weathers the winter and blooms much earlier than the seeds which are spring-sown. This at once suggests that some seeds may do well if sown in autumn, say, in late August or early September. The following selection of the above should be tried in this way: candytuft, clarkia, cornflower, coreopsis, eschscholtzia, godetia, kaulfussia amelloides, leptosiphon, nemophila, saponaria, silene. With most of these success will be attained where the winter is not extremely rigorous.

HARDY BIENNIALS.

Name.	Height.	Colour.
Canterbury bells	2 ft.	carmine, blue, rose, and white
Dianthus	9 in. to 1 ft.	from dark crimson to white
Foxglove	2 to 4 ft.	from purple to white
Giant evening primrose	4 ft.	yellow
Glaucium luteum (horned poppy)	2 ft.	bright yellow
Honesty	2 to 3 ft.	red, purple, and white
Scabious (sweet)	3 ft.	from dark crimson to white
Sweet-william	1 to 2 ft.	from dark crimson to white
Wallflower	1 to 2 ft.	from dark crimson to yellow

Hardy Biennials.—The name "biennial" denotes the method of growth encouraged in these plants by gardeners rather than the natural habit of the plant. Most of them are really perennials, but give the best bloom in the second year, after this deteriorating from season to season. A few foxgloves should be grown from seed (the best time for sowing, as for most of the above, is the beginning of June), separated out as soon as they are large enough, and, in October, placed in some spot where they do not need to be moved for some years. The gradual decline in fineness of flowers will be very marked. So that a biennial is a plant which the garden-worker grows from seed one year and cuts blooms from the following year, throwing the plant out at the end of the second season, because its later blooming will be poor. Many plants are so treated. The names on p. 155 merely represent a selection.

HALF-HARDY ANNUALS.

Name.	Height.	Colour.
Aster	9 to 18 in.	from crimson to white
Ageratum	6 to 12 in.	blue and white
Antirrhinum (may well be grown as a perennial after the first year)	6 in. to 3 ft.	from crimson to white
Humulus (Japanese hop)	8 to 10 ft.	climber with variegated leaves
Marigold, French	4 in. to 1 ft.	brown and yellow
Marigold, African	2 ft.	orange
Nemesia	9 to 15 in.	from crimson to white
Pentstemons (may be grown as a hardy perennial after the first year)	18 in.	various
Phlox Drummondii	4 to 6 in.	from crimson to white
Salpiglossis	3 ft.	crimson, yellow, and blue
Schizanthus	1 to 1½ ft.	from dark crimson to pink
Statice (sea lavender); some are perennials	1 to 1½ ft.	mauve, yellow, and white
Stock, ten week	9 in. to 1½ ft.	crimson, blue, and white
Zinnia	1 to 2 ft.	from scarlet to white

Half-hardy annuals are, for the most part, plants which have been taken from countries which enjoy a much warmer spring and early summer than Britain. As the degree of warmth necessary for germination is not to be had in the open in Britain at this season, the result is that these plants must pass the early period of their growth in a frame, where atmospheric conditions are more suited to their requirements.

Rose plot.—It is impossible in the space available to do more than indicate the method of pruning in the case of a few good roses, allowing the student to work out the distinctions between hybrid perpetuals, teas, hybrid teas, polyantha, Chinas, etc., for himself.

12. Pruning of roses. Frau Karl Druschki (H.P.).—Cut out all weak wood at the base. Of the stronger growing shoots, cut out close to the base all save from four to six of the strongest, retaining those which keep the bush cup-shaped, and cutting out all those in the centre. The shoots retained should merely have their tips cut off, and the top bud retained should point outwards from the centre of the bush.

Use the knife, cutting from the centre of the bush outwards, so that the cut is slanting and the finish of the cut is on the same side of the stem as the top bud retained. Prune in the same manner as the above: Maman Cochet (T.), White Maman Cochet (T.), Marie Van Houtte (T.), Lyon Rose (H.T.), La France (H.T.), Caroline Testout (H.T.), Bessie Brown (H.T.), Cecile Brunner (P.), and Fabvier (Ch.).

Treat the following as above, save that the shoots retained are cut back to half their length: Ulrich Brunner (H.P.), Mme. Hoste (T.). Souvenir de Pierre Notting (T.).

Treat the following two as above, save that only from three to five shoots are retained, and these cut back to from four to seven buds: Mrs. John Laing (H.P.) and Hugh Dickson (H.P.). The following are similarly treated, save that they should be cut back to two or to three buds: General Jacqueminot (H.P.) and Mrs. R. G. Sharman-Crawford (H.P.).

Gloire-de-Dijon, Grüss an Teplitz (H.T.), and the climbers, Dorothy Perkins, Hiawatha, Lady Gay, and Crimson Rambler, should merely have old unprofitable wood cut out each year.

Every rose in the plot must be named. Begin to prune about April 1st. By the time the pruning of the above roses has been mastered, a good introduction to the subject of rose pruning will have been gained. The general principles of pruning are discussed in Chap. XII.

CORRELATED EXERCISES.

1. How do you account for the fact that beet, carrots, turnips, etc., develop large globular or spindle-shaped roots in the first year's growth?

2. What distinctions do you observe between an underground and an aboveground stem? What similarities?

3. A potato tuber planted in spring is found to have changed in appearance considerably by the time the crop is being lifted in autumn. Describe such a tuber. Account for the changes which have taken place.

4. A potato tuber weighing 2¾ oz. was planted in spring, and in autumn the crop lifted from the resulting plant consisted of 25 tubers of an average weight of 1⅞ oz. each. What percentage of increase was this? What is the derivation of the word "autumn"? Is it well termed "the season of increase"?

5. In 1900 the Channel Isles, Jersey in particular, supplied Britain with potatoes valued at over £1,000,000, *i.e.* half the value of our whole import of potatoes. Show how climatic conditions render so small an island capable of growing a crop valued at so much money.

6. Make lists of garden weeds which disperse their seeds by scattering, by wind, and by animals. Can you distinguish any different methods of scattering?

7. How do you account for the fact that disbudding of roses causes improvement in the blooms?

8. Explain how it is that too close planting of potatoes, etc., is not profitable.

9. Describe the changes which occur in a potato tuber which has been set to sprout in light. In what respects does the growth differ from that which takes place in darkness?

10. What benefits result from having potatoes well sprouted previous to planting?

11. What is the exact effect the application of a considerable amount of nitrate of soda has upon a cabbage plant?

12. How is it that if but half-a-dozen or so plants be grown in each manurial plot, the results must not be accepted as absolutely final?

13. Has the term "biennial" as applied to vegetables the same meaning to gardeners as the same word when applied to flowers? In what respects do they differ?

14. Describe the colour of foliage and method of growth of Tea-scented, Hybrid Tea, and Hybrid Perpetual roses.

CHAPTER IX.

PROPAGATION OF PLANTS.

Continuing the species.—It is characteristic of all living organisms that they possess the power of producing young of the same species. From the lowest to the highest form of life this holds good, though the methods of reproduction may differ in detail. A bacterium, certain forms of which are described in Chapter X., multiplies by a simple splitting of the cell of which it consists, each half developing into a form similar to the original.

Some plants continue the species by the process of developing new young plantlets from certain pieces—root, stem, or leaves—which become detached from the parent, and grow into separate plants.

The more common way is reproduction by means of seeds. Seeds are formed by the union of two cells, usually from separate plants; one cell is contained in a pollen-grain and the other in an ovule, each of which is a part of the flower of the plant. This union is made possible by the action of bees and insects as they carry pollen grains from one flower to another in their search for honey.

1. **Seeds.**—Collect at least one plant of each of the following types: (*a*) Those which spring from seed in the early part of the year, grow, bloom, bear fruit and die a natural death, all in the same year. These plants are called *annuals*. (*b*) Those which grow up from seed one year, develop stem and leaves, and remain bloomless until the following year, when they flower, fruit, and completely die away, thus running their course in two years. These plants are *biennials*. (*c*) Plants which grow on from year to year, their leaves, and in most cases their stems, dying away in autumn; but their roots storing up the energy which enables

them to develop buds, shoots, stems, etc., each following year. These plants are called *perennials.* Make a table containing each of these three headings, and fill it up as the work proceeds until you have thus classified every plant cultivated in the garden. Do all these plants as a rule produce seeds?

All plants—annuals, biennials, and perennials—make provision for continuing their kind, *i.e.* producing plants of the same species. Most attain their end by means of seed, but most perennials are propagated both by this method and by the rooting and subsequent growth of pieces of the plants themselves.

Annuals would seem to live merely that the existence of a succeeding generation may be made sure; and the number of seeds produced by any one of them usually runs into thousands. This seed, we have found, consists of a young plant with a store of food-substance attached, which must represent the expenditure of much energy on the part of the parent. So bent is the average annual upon providing a race of its own species to succeed it, that persistent cutting away of its blooms results in most cases in renewed activity on the part of the plant, and in a fresh supply of blossoms. Indeed, by allowing an annual to set in fruit the garden-worker practically encourages paucity of bloom and shortness of life, for having once seeded, the plant usually suspends operations and dies.

2. Half-hardy annuals.—In all seedsmen's catalogues will be found a list of "hardy" and of "half-hardy" annuals. To find out what the term implies, take two or three seeds of a half-hardy and of a hardy annual, and sow them at the same time as ordinary annuals in a marked spot in the garden. Watch for their appearance.

On the date given in the calendar of garden operations, half-hardy annuals must be sown under glass. Having done so, try to find out the reason for this method being adopted. Get a clear glass bottle, stopper it tightly, place in the sun for some time, insert a thermometer fitted with a collar as already advised (p. 2), stopper again, and after three minutes take the readings. Also take the temperature of the atmosphere outside the glass bottle at the time. Record. Can you give the cause of this difference?

The use of cold frames.—A garden frame of some kind is necessary for the growth of half-hardy annuals, for, as has just been found, they cannot be brought to germinate in the open in early spring. However, if sowing be delayed till the soil is thoroughly warmed, it will be found that half-hardies can be grown quite well outside; but of course they bloom much later than do those raised in a frame. Thus we have found that a certain degree of warmth is necessary for germination in this case, and when the proper temperature is not provided the seed rots away.

The probable explanation is that as starch itself—of which the stored-up food of the seed consists—is insoluble in water, it must be made soluble, as some form of sugar, ere it can pass by absorption from the seed-leaves into the cells of the young plant. The seed possesses the power of bringing about this conversion, for it gives rise to a certain **ferment** which acts upon the starch and brings it, as sugar, into solution in the soil-water absorbed. This fermentation, however, can proceed only when a certain temperature is secured; when the soil is too cold, decay sets in instead of fermentation.

The frame used has no bottom heat. What heat it does contain is absorbed from the sun. The heat rays of the sun have the power of passing through the glass, and thus the temperature inside is raised. But this heat is imprisoned; it cannot pass outwards again, since glass cannot transmit dark heat rays; and thus the temperature inside the frame rises. In addition to this, if a "wet and dry bulb" thermometer be inserted in the frame, it will be found that the atmosphere inside holds much more moisture in suspension than does the air outside. The imprisoned heat causes the moisture in the soil under the frame to be evaporated, and this vapour passes into the air contained in the frame. From the inside of the frame it cannot escape either by evaporation or condensation.

Thus by using a cold frame the gardener provides for the seed a higher temperature and a moister atmosphere than were it sown in the open, and these conditions will be found to approach very closely to the conditions of the native habitat of the plant. In most cases, what are termed half-hardies were fancied for their blooms in some foreign region warmer during the germinating season than is our spring climate. They were brought to this country and half acclimatised.

3. Size and quality of seed.—Sow one dozen of each of the following seeds : pea, bean, radish, turnip, choosing in each case twelve of the largest seeds in the packets and twelve of the smallest. Watch for differences in the size and strength of the seedlings, and continue observations as the plants develop until cropping time.

Large and small seeds.—As a rule, a large seed like the bean contains so great an amount of food-store that the plant is able to absorb material from the soil by means of its roots long before the store is exhausted ; so that little difference may be found between bean plants grown from large and those from small seeds. In the case of the radish, however, the contrary is usually the case. This crop must be grown quickly and continuously to obtain a fine crisp root. Sharp early growth is indispensable for this, as the crop remains in the ground for a comparatively short period. Thus, whatever results in providing the very young plant with a readily available supply of food, furthers rapid growth and helps to produce a finer root. A larger seed answers this requirement. Turnips, on the other hand, remain so long on the land that any little backwardness at the early stage, owing to smallness of the food-supply in the seed leaves, can usually be made up.

But a much greater source of poor seed is the weather. A bad season in one year—too much wet or too much heat—usually means that but poor seed is to be had in the following year. In the former case the seeds are under-ripe, and as a result they tend to lose their vitality quickly, so that while they may germinate next year, they may also fail to produce plants. The best seeds, those of highest percentage of fertility, are produced by plants of healthy vigorous growth ; and a dry, hot season which results in stunted vegetation is followed usually by a year of poor seed. The pity is that seeds from plants of poor growth, if they are fully ripe, are hardly distinguishable from those grown under favourable conditions. The only safeguard for the gardener, then, is to deal with a reputable firm.

4. Depth at which to sow.—If room in the garden is limited, many experiments may be performed successfully in flower-pots or deep boxes. Arrange a series of sowings of different seeds, the depths ranging from just under the surface to 6 inches if possible. See that the correct degree of moistness is maintained. Label each pot carefully with name of seed, depth of sowing, and date. Keep a record of results, showing the date of appearance, etc. Keep the pots in the open, sunk in the earth to within half an inch of the rim. If there is no room for this in the garden a vacant space should be found outside the garden ground.

Depth of sowing.—The size of the seed naturally suggests the approximate depth at which it should be sown, but two conditions determine the depth if success is to be obtained. The seed must have an adequate supply of moisture, and it must be able to force its way to the surface of the ground once it has germinated. Small seeds naturally need less moisture than large, and therefore they may be sown nearer the surface. For example, it will be found that broad beans sown at the depth of $\frac{1}{4}$ inch fail to germinate so well as those placed 3 inches deep, because of the smaller supply of soil-moisture existing at the former depth. Sweet alyssum seeds, on the other hand, germinate best at the depth of $\frac{1}{8}$ inch, while if they be sown at 2 inches, as are beans, they do germinate, but fail to push their way up to the surface on account of the weakness of their structure compared with that of beans.

5. **Transplanting.**—Tear up a seedling harshly, and carefully lift out another of the same size, taking a ball of earth with it by means of a trowel. Examine the roots of each. Which has retained the greater number? What happened to the root-hairs of the former?

Transplanting.—This operation is one in which most amateurs fail. By removing a plantlet from its position carelessly, many minute rootlets are broken off, all root-hairs are destroyed, and when the young plant is placed in its new quarters it is without the apparatus which absorbs water from the soil. Yet transpiration proceeds from the plant by means of its leaves; and the result is that, receiving little or no water from the soil and giving off much to the air, the plant soon begins to wilt and will in all probability die. Even should a few absorbing roots have been left, these are so incapable of supplying the necessary amount of moisture that the plant receives a bad set-back and may make but poor growth throughout the season.

The better method is to remove the plantlet from its position, disturbing the roots as little as possible and retaining a good ball of soil around them, so that the minute root-hairs are left on and do not lose contact with the particles of soil. Thus the greater part of the absorbing roots are retained, and when the plant is placed in its new position, with soil packed closely home around its roots, almost immediately it resumes its work of absorbing moisture. To cover any deficiencies that may exist, a quantity of water should be poured in at the roots, while to decrease the danger of wilting as a result of transpiration it is best to transplant only in cloudy or moist weather.

When the sun is shining strongly, the air is as a rule dry, a condition which encourages transpiration, while in moist weather the opposite is the case. Should it be absolutely necessary to transplant in sunny weather, the work should be done as late in the day as possible, and to reduce transpiration a flower-pot should be inverted over the plant. Should a supply of pots not be to hand, caps made of brown paper will serve the purpose.

6. **Propagation by division.**—In filling up an herbaceous border, if a large clump of any plant be available do not set it in as a whole. Cut it up with a spade into the number of pieces desired. Plant these out and watch whether they grow or not.

Propagation by division is the simplest form of reproduction. Each piece consists of roots and either stems or dormant shoots. Thus all that is necessary to constitute a plant is present, and if well planted, the piece is almost certain to grow. Each part of the clump, however, is not likely to produce plants of equal strength, in fact the centre seldom produces good growth. This is but natural, for each year fresh growth of roots and buds develops round the edge of a clump, and thus the oldest part is in the centre. Therefore, in dividing an old stock, the garden-worker should cut off only the outside ring of roots and shoots, and plant these, throwing away the old central part.

Propagation of chrysanthemums.—Two special cases of propagation by division need mention here, namely, those of chrysanthemums and strawberries. The recognised method of increasing the stock of the former is that of taking cuttings, but if inquiry be made it will be found that a large percentage of growers merely take the young rooted shoots which appear round the outside of the plant. These are broken from the older plants in spring, and if planted under suitable conditions produce very good blooms. The old stocks may either be left outside throughout the winter, receiving the necessary shelter, or may be kept in a cold frame until such time as the young shoots are removed. It is possible, however, that by this method the blooms produced may not be quite so large as those to be had from cuttings.

Propagation of strawberries.—Strawberries send out long side stems called **runners.** These grow out from the parent plant, and will be found to be absolutely free from side growths for some considerable length. Then a leaf will be found growing from the stem, and in the axil of the leaf a bud usually grows. The point where the leaf springs from the stem is called a **node**, and if this point rests on the ground it usually sends out roots which grow downwards into the soil. The growing bud is supplied with food from the parent plant until such time as it is able to obtain sufficient material from the soil by means of its own roots, and then the stem of the runner gradually ceases to function, and dies away.

If left where it grows, the rooted shoot develops into a full-sized plant in the following year, but the gardener's method is usually to remove the growing plantlet so as to keep his strawberry plants in line and prevent overcrowding. The runner is cut away close to the parent, the young plant is removed, retaining a ball of earth around the roots, and is then planted in line along with others, where they are kept until the following spring, when they are planted out to form a new strawberry bed.

7. **Propagation by cuttings.—Woody cuttings.**—About the time mentioned in the calendar of garden operations, obtain a few shoots of each of the following: willow, blackcurrant, gooseberry. Make them different lengths. Cut the base across, below a bud in some cases, above a bud in others. Cut off the tops of some; leave others uncut. From some shoots pinch out with the finger and thumb all the buds along the whole length, from others, only from the part which is to be placed underground, from others none at all. Plant some with just the tip appearing above ground, some at half their lengths, and others inserted but an inch or less. Label each cutting carefully, giving all particulars regarding it, together with date, and watch the results, recording in each case.

Place a few of each of the above shoots in a jar containing water, set it to stand in the light, and note development.

Growth of cuttings.—Mutilation or injury of plants usually results in what is called **adventitious growth.** What this means will be explained easily to the garden-worker who has had a little experience in clearing dandelion plants from a garden path. Let him break the root, tearing away the whole of the leaves and the crown as well, and in a short time up comes the dandelion plant again. It has developed a new bud which grows up into crown, leaves, and, if it be permitted, flowers. Raspberry roots also seem to possess the power of sending up stems which do not originate in the original stem, but in the root itself. Such growth is called adventitious.

This power, however, is not restricted to roots, in fact they are really the exception, but practically all the young parts of stems—some conifers and a few others excepted—are found to develop roots, if cut off from the parent plant and placed under suitable conditions. And the rule is that the plant develops just those organs of which it has been deprived by injury. Cut pieces of stem produce roots; a growing branch cut back and deprived of its leaves usually begins leaf-growth in dormant buds closer to the stem than is the cut; some leaves even—the begonia, for example—have the power of sending out roots and a shoot which will by and by grow up into a plant.

The power which plants possess of replacing by growth the part which has been cut away has been made much use of in the propagation of garden plants. In a number of cases, indeed, so strong is this tendency that all that is necessary is to bend down a branch, cover the leafless part thoroughly with earth, and the covered part will send off roots, requiring but severance from the parent to become a separate plant. Rooting is accelerated, however, by injuring the portion placed underground, and this method, which will be described later, is called **layering**. But in some cases it is inconvenient to bend down the shoots, and so they are cut wholly away and treated as cuttings.

8. **Kinds of cuttings.**—Search the garden for plants which, when cut, show hard wood on exposure, and others in which no woody tissue is present, the stem being green and fleshy all through, save for a hollow tubular space in the centre of some. Of the former, black, white, and

red currants, and gooseberries, may be mentioned, while the latter include fuchsia, lobelia, marguerite, etc. The former are called *woody*, and the latter *herbaceous*, cuttings.

9. **Herbaceous cuttings.**—The method of increasing stock by woody cuttings has been discussed already. The treatment of herbaceous cuttings is different in one or two important details. Choose the cuttings from the side-shoots of the plant ; cut slantwise clean across, a little below a node or leaf ; trim off the lower leaves, and the cuttings are ready for inserting in the soil. The soil should be a potful of compost, of leaf-mould, sand, and rotted turf. Place a piece of broken flowerpot over the hole of the pot. This is merely to keep the soil from working its way out, and there is no special magic associated with a piece of broken pot save the superstition of the ages. A stone is quite as good. After that, proceed as seems good, taking care that the compost is packed tightly round the side of the pot. This prevents any water which may be applied from finding a ready passage downwards and being of no benefit to the plant.

Six cuttings may be set in a 6-inch pot. Make a hole with a round piece of wood or lead pencil, a little shallower than the depth at which you wish to insert the cutting. Place the cutting in the hole, pressing it well home so that its base is certain to be in contact with soil. With the fingers press the soil tightly around the stem. Place the pots in a tub containing about an inch or so of water. Leave until the surface soil is wet. Place on a layer of ashes in a frame. Close the frame, and cover the glass with matting. Each day open the sash of the frame a very little for about half-an-hour, and after a few days remove the matting. Water sufficiently but not overmuch. Harden off after three weeks by opening the lights 6 inches or so for a few hours in the middle of the day, increasing the distance and the time until after about three more weeks the lights may be removed during the day. The plants must be kept in a cold frame all the winter and set out in spring. The frame should be covered with matting during severe frost.

Root-formation in cuttings.—The distinction between woody and herbaceous cuttings consists in the fact that the former contain in their woody tissue a store of food-substance, which the cutting may use until it can absorb food-material by its roots ; in the latter case no such supply is present. This distinction is the cause of the necessity of different treatment.

Growth implies food ; and this latter is provided in the cutting when the shoot is woody. The herbaceous cutting has no such supply. Food is manufactured by leaves, so some of these are left on in the case of herbaceous cuttings. But by the leaves, also, transpiration takes place, so if the cutting be placed in the open, loss of moisture by transpiration is so great that, receiving no additional supply since no roots are present, the cutting wilts and dies. However, as has already been seen, the atmosphere in a frame contains very much more moisture than that in the open usually does, so that the conditions which encourage much transpiration do not exist inside the frame. Thus this difficulty is overcome. But bright, warm sunlight also furthers the giving off of water, hence matting is placed over the glass to shield the cuttings. Without light, however, the carbon of the air cannot be fixed by the leaves, nor therefore can food be manufactured; so the matting is removed partly and the sash slightly opened for a short time each day. Carbon fixation is also furthered by the higher temperature which exists inside the frame.

Woody cuttings having plenty of food in store, are taken later in the season when the leaves have fallen, and thus lose little or no moisture by transpiration. Manufacture of food, higher temperature, and a moister atmosphere are not necessary. They "strike," or root, quite well out of doors.

Method of growth.—In both cases adventitious roots arise in the part underground. As a rule they come best from a node or bud, and the part of the cutting below this point rots away. The base of the cutting in many cases gradually becomes covered over with a protective corky covering which prevents loss of sap, the roots gradually become fibrous, buds grow into shoots, and a new plant is formed. Sometimes when buds are allowed to remain on the underground piece, they shoot and grow out above ground as branches. This type of growth results in a **bush-formed** plant, suitable in the case of currants. When a **tree form** is required, *i.e.* an upright stem bare for some little distance before branching occurs, it is safer to pinch out all the buds save a few above ground. That is, if the cutting be 8 inches long, 4 inches would be sunk in the ground, and upon the upper 4 inches two, three, or four buds would be left as required. This is suitable for gooseberries, etc. Very often, however, the underground buds remain dormant, partly as a result of the low soil temperature in early spring, partly because the passage of the ascending sap is strongest in the direction of the tip of the shoot, and those buds higher up develop.

10. **Layering** is usually done from late July till mid-August, but many prefer to layer carnations only when flowering has ceased, and are successful too. The student must judge for himself whether layering his plants while they are still in bloom spoils the blossom, and act accordingly.

Two or three days before beginning operations, give a thorough watering to the roots of the carnation plants from which layers are to be taken. Select the shoots, preferably young healthy side-growths, and cut off the lower leaves. If the worker then fork over the soil around the carnation, carefully breaking up lumps and sifting the soil through his fingers, he will have done what will help rooting considerably. If in addition he throws in a handful of sand just where the layer is to lie, he will have done better, while if the fetish of professionalism has a strong hold upon him, he will most carefully make a mixture of loam, leaf-mould, and sand, the proportion varying according to the particular professor for the time believed in, and he will then consider he has done all he can to assist rooting. Perhaps he has, but it is a question whether the layers will root in any greater proportion than in the case where the soil was merely well broken up with a little sand added. Find out by attempting all three methods.

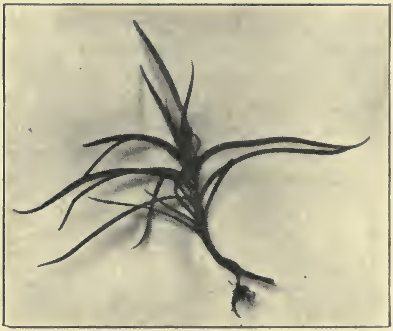


Photo Mr H James

FIG. 61.—Layered carnation showing rooted tongue.

Now with a sharp knife cut almost half-way through the shoot from the under-side, beginning the cut just below a node or joint and cutting right through it. Then turn the edge of the knife so that it points along the length of the stem and cut upwards through another node, just as though the stem were being split up the middle. Bend the shoot downwards so that the cut is well open, and the projecting tongue of wood is well buried in the soil, or sand, or compost, which also comes in contact with the cut surface above. Peg down with a wire staple, a piece of wood, or even a hair-pin, and cover well with soil or compost. Pack the earth tightly around the layer, give a good watering without washing away the soil, and keep moist for the next three weeks.

By the end of September to the middle of October, the layer should be well rooted (Fig. 61), may be cut off from the parent, and placed where it is to flower, receiving a mulch as protection.

11. The principle of layering.—Remove a ring of bark from a small branch, taking care not to injure the wood underneath in any way. Also twist a wire tightly round another branch. Record dates, and watch what occurs. Do the leaves beyond the ringed part droop and fade? Must they then be receiving moisture from the soil? Where must the path of the ascending moisture be? Note what happens to the branches throughout the year (Figs. 47 and 50).

The principle of layering.—Injury which interrupts natural growth is not at all uncommon, but the results of Exp. 11, without going any further, explain well the principle of layering. On account of the fact that the removal of a ring of bark in nowise interrupts the ascent of sap to the leaves, it is concluded that the path of the ascending sap is not in the bark, and therefore it must be in the wood of the branch. But it is not uncommon to see an old willow tree, quite hollow inside, yet bearing leaves and showing all the signs of life. So the fact that the sap cannot ascend in the centre of the wood is the next step arrived at. Indeed, it has been found that the soil-moisture containing raw food-material in solution passes upwards in the plant in the outer layers of the wood which underlies the bark.

If the plants in Exp. 11 be examined at the end of a year, it will usually be found that that part of the ringed or wired branch which is between the stem and the treated part has not put on any increase in thickness during the year. On the other hand, a marked and unnatural swelling will in almost every case be found above the ringed part or the position of the tightly drawn wire (Fig. 50). Evidently there has been much growth above, but none below the ringed point. Now growth implies a supply of food; food is received by the stem from the leaves; and evidently the food supply has been cut off from the lower part of the branch by removing or cutting the bark. Hence the accumulation of food just above the injured part, a sign that the path of the descending food is not in the uninjured wood, in fact is in the innermost layers of the bark.

Now, in layering, the shoot is not wholly disconnected from the parent plant. This results in a steady ascent of soil-moisture to the leaves, and as steady a downward flow of food from the leaves to the stem by the uncut part of the shoot. But part of this downward flow is interrupted by the cut part, and while some food passes down through the uncut portion and sustains life in the shoot, much accumulates just above the cut and helps to encourage the formation of roots there.

12. Choosing cuttings for budding.—About the end of October or the beginning of November, search the hedgerows for current year's growths of the common dog-rose (*Rosa canina*) or of the briar. Choose shoots which are firm to the feel, straight and strong in growth, and somewhat thicker than a lead pencil. Cut them from 12 to 15 inches in length. These, when rooted, form the **stocks** which are to be budded.

13. Preparing the stock.—Cut across near the foot of the cutting in a slanting direction, just below a bud. Allow 8 to 10 inches of length, and then cut in a slanting direction about $\frac{1}{8}$ of an inch above a bud, so that the finish of the cut and the uppermost bud retained are on the same side of the stem. Three or four of the topmost buds must be retained for subsequent growth, but all those below this point should be removed with the point of a knife. The cutting is now ready to be inserted in the soil.

Dig out a trench, facing south if possible, about 6 inches deep, the north side of the trench not being cut vertically, but sloping at an angle of about 60°. Lay in a good layer of sand right along where the heels of the cuttings will lie when about 4 inches of their length are left above the ground line. Place the cuttings in position at this depth, setting them 3 to 4 inches apart, when they will lie with their heels buried and their length sloping somewhat towards the north. Cover the heels well with sand, fill in the trench with earth, and tread the soil well down so as to make it as compact as possible. The surface inch or so may be left loose.

Leave the cuttings in this position, merely clearing away all weeds, until the following October. Now dig them up, injuring as few of the roots as possible. Should there be evidence of a taproot, cut it back, and prune back the roots as in the case of roses. Now plant out in lines, or, if but one or two are being treated, in their permanent quarters, preparing the soil just as for roses (p. 209)

Plant much shallower than the point to which the cutting had been placed in the earth; in fact, have the junction of roots and stem as close to the surface of the soil as possible. Make the soil compact around the roots, and ridge the earth well up to the stem. Again do nothing save remove weeds until the following July.

Choosing cuttings.—The burnet, or any of the dwarf-growing kinds of wild rose, are of little use for the purpose of cuttings. One of the reasons why the rose is budded on to a briar root is that the latter is much more vigorous in growth, and therefore the ascent of sap is much stronger than in the rose on its own root. This is not always the purpose of budding; vigorously growing apples, for example, being budded on a stock the growth of which is not nearly so strong, thus producing plants of dwarf habit. In the case of roses, however, the opposite is what is wanted, and should a dwarf briar be chosen, a dwarf, weak habit of plant will result.

If thick coarse shoots be chosen for cuttings, they often fail to stand the winter on account of their usually being unripe when cut, and as they contain so much soft pith they fall an easy prey to frost.

Preparing the stock.—The same laws with regard to rooting hold in the case of briar as of gooseberry cuttings. As the rose bud should be inserted as close as possible to the root of the briar, so that the junction of briar and rose may be buried a little below the surface of the soil, all the buds on the part of the briar which is to be buried should be removed. This to some extent prevents rooting from taking place all along the buried portion, and renders impossible the growth of suckers. All the strength of the plant is thus thrown into the main stem.

Cuttings strike most readily if the soil be warm and not over-wet. Both these conditions are encouraged by the layer of sand placed around the base. By placing the cuttings in a slanting position, the bases are brought closer to the surface of the soil, and thus come under the warming influence of the sun's rays sooner than if they were buried more deeply.

In removing rooted cuttings to the position where they are to be budded, shallow planting is advised. Any upper roots should be rubbed off, and thus the rose bud may later be inserted as close to the root of the briar as is desired. By earthing up, the bark of the stem is kept moist, and in this condition will easily part from the wood.

Stocks prepared as described above may very well be planted in the garden proper at the end of the first twelve months. In the following July they will be budded, and early in the following summer will bear their first blooms. The plant is called a "maiden" at this stage, and it must be remembered that many roses bear their best flowers at this period, and should therefore not be left in some out-of-the-way corner.

14. Budding operations.—Decide which roses you intend to bud upon the stocks you have grown. Be sure you choose only roses which have borne blooms good and many.

From the middle of July to the middle of August is the best time for budding, and a dry day should be chosen, as otherwise particles of soil are apt to find their way into the wound.

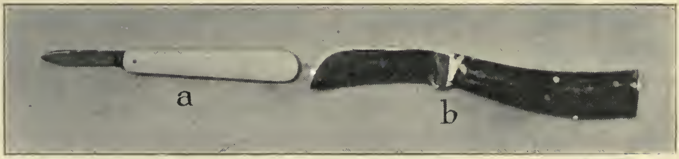


Photo Mr H James

FIG. 62.—*a*. Budding knife; *b*. pruning knife.

Choose the healthiest of the current year's shoots from the rose bushes decided upon. The wood must be well ripened, a sign of this being that when the spines are pushed sideways with the thumb they snap off sharply. The buds should also be plump and swollen, but in no case started into growth.

Cut off a shoot or two from each plant, remove the spines, tie the shoots together, label them, and place each bundle in a pailful of water, from which they are removed only when the buds are to be cut off.

Remove the earth from around the stem of the briar, and thoroughly wipe away all particles of soil, etc., with a piece of coarse cloth.

Now take one of the prepared shoots. Cut off the leaves, leaving about an inch of stalk by which to hold the bud when it is cut. Rather take buds from the middle of a shoot than from the base or the point. Place the shoot in your mouth, where it will be out of the way and at the same time handy when required.

With a budding knife (Fig. 62) make an upright cut about 1½ inches long in the bark of the briar-stock, fairly close to the root. Across the top of this, with a rocking motion of the knife, make another cut at right angles to the former and extending not quite half-way round the stem. Great care must be taken that only the bark is severed, the wood not being cut into at all.

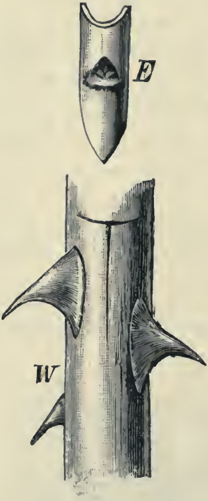


Fig. 63.—Budding roses. *W.* Stock ; *E.* Bud.

Hold the rose-shoot base upwards in the left hand, the palm of the hand being toward you. Insert the blade of the budding knife about an inch beyond the bud to be taken, cut downwards so that the blade sinks inwards as it passes beneath the bud, and, when this point is past, incline the knife blade outwards again so that the finish of the cut is at a point about an inch on the other side of the bud.

Examine this piece cut off. Distinguish the following : bud, bark, and a thin section of wood.

Now hold this piece between the finger and thumb of the left hand, so that the bud is pointing earthwards, insert the point of the knife between the wood and bark, prise slightly until a hold can be obtained, and then sharply jerk out the piece of wood.

Examine what is left. Do you note a depression on the inside of the bark, just under the outside bud? If you do, throw this bud away. It is of no use. Try again, and if necessary again, until you manage to obtain a bud in which the base of the bud-eye is level, or almost level, with the inside of the bark.

Cut off, to a blunt point, the part of the bark which is below the bud, leaving about half-an-inch of bark below the bud-eye. Fig. 63 illustrates the method of cutting of stock and bud. The piece of leaf-stalk has been here removed so as to show the bud distinctly.

Insert the thin part of the handle of the budding knife in the upright cut made in the bark of the briar, and loosen the bark from the wood for a distance of about a quarter of an inch, working from the top and downwards as far as the cut will allow. Be careful not to tear the bark in the operation.

Now insert the pointed end of the bud into the top of this opening and press downwards, keeping the fleshy exposed surface of the bark of the rose-bud close up against the white moist wood of the briar. When it has been pushed home as far as possible, cut off short the upper part of the bark of the bud. This cutting should be made just at the transverse cut on the briar, so that the bark of the bud may slip wholly under the bark of the stock.

Press together as closely as possible the lips of the vertical cut on the briar. Tie up with bast, or raffia, so as to keep the stock and bud in close contact. Two or three turns of bast should be placed below the bud and two or three above, but the bud itself must not upon any account be covered up or tied over. No further attention is necessary till the following spring, when the raffia should be cut away (if it has not rotted in the meantime), thus allowing the bud to swell. In spring, cut away the briar-stock about a quarter of an inch above the junction of briar and rose-bud. Thus the latter receives all the food-material absorbed by the roots.

Budding operations.—July and August are best for this purpose because at this time the bark of the stock has not yet become hard and corky, and as moisture is still ascending, the bark usually parts readily from the wood. Should it refuse to do so, give the stock a thorough drenching with water and wait for a day or two. If the stems have previously been well earthed-up, such an operation should not be necessary, for the moist earth prevents the bark from becoming hard close to the roots.

This period is chosen also for another reason. By this time the sap has begun to ascend with very much less intensity than it did in spring, and there is little danger of the amount of moisture supplied causing the bud to begin to grow. This would be most harmful, for the soft young wood could not withstand the winter. A second danger might result if budding were done in spring, when the ascent of sap is very vigorous. The bud might actually be grown over, for the plant naturally sets itself to heal up the wound. In fact such healing is but the plant's method of protecting itself from loss of moisture by evaporation from the cut surface. Should the wound completely heal up, the bud in all probability would be crushed to death in the process.

The leaf is cut from the bud, of course, for the purpose of preventing large loss of moisture by transpiration previous to the time when the bud becomes joined by growth to the stock. It is extremely important, too, that everything should be in readiness before the buds are removed or the bark of the stocks cut. In the warm weather of July any dallying over the work results in loss of moisture by evaporation from the cut surfaces, than which nothing is more detrimental to subsequent union of stock and bud. The more quickly each bud is cut, inserted in its position, and the wound tied up, the greater are the possibilities of the success of the operation.

The budding of fruit trees may be done in exactly the same manner. Of course the stock taken is not the briar. Plants have been found to bud and graft, as a rule, only when stock and scion (Exp. 15) are closely related botanically. The apple, for example, succeeds well on the **paradise stock** and the pear on the **quince stock.** But a bare patch on a branch of an old fruit tree may profitably be budded, choosing preferably a bud from a young tree which has already shown itself fertile.

15. Splice-grafting.—Get a branch of almost any forest tree : sycamore does very well. Choose one not more than three-quarters of an inch in diameter, and cut off a piece which is free from branching twigs. This piece may be any length from 9 inches to 2 feet, but a convenient length is about 18 inches.

With a sharp pruning knife cut this into two pieces of about equal length. Place the base of the thicker part on the ground, and set it upright as though it were the cut-back stem of a young tree growing out of the soil. With a slicing action of the pruning knife make a cut beginning about 2 inches from the top, passing upwards at an angle of about 30° from the vertical, and finishing at the bark on the tip of the branch at the opposite side of the wood from which the cut was begun. The piece of branch should now appear like *a* in Fig. 64. The stock is now prepared.

Treat the top piece of the sycamore branch which has been cut off in the same way, with this difference. The cut must begin on the opposite side of the wood, and the end of the cut should be on that side of the wood on which the cut was begun in the piece already treated. To make certain of this, hold in your right hand the piece already treated, so that the beginning of the cut is turned to your left. Hold the second piece of branch in your left hand, growing point upwards, raising it above the lower piece. Drop the latter, and place a mark about 2 inches up on the bark of the upper piece on the side turned to your right hand. From this mark cut downwards in a slanting direction at the same angle at which you cut upwards before (*b*, Fig. 64). This part is called the **scion**. The two cut surfaces when placed together should fit to each other exactly. If they do not, they must be dressed until they lie flat to each other throughout their entire lengths. Further, when they are pressed closely together, the result should be a straight branch. Should the top piece strike off at an angle to the bottom, more paring is necessary until the whole is quite straight (*e*, Fig. 64).

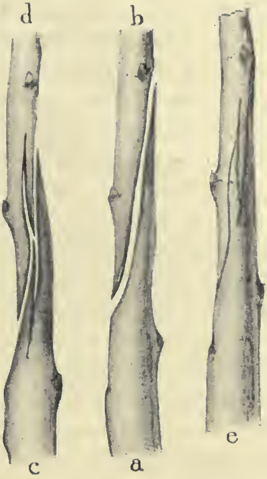


FIG. 64.

a, *b*. Stock and scion; showing method of splice-grafting.
c, *d*. Stock and scion; showing method of whip- or tongue-grafting.
e. The graft ready to be waxed.

Splice-grafting.—The principle of grafting is essentially the same as that of budding, *i.e.* bringing a piece of plant containing a dormant shoot in the form of a bud or buds, in contact with a rooted plant usually of the same order botanically, in such a way that the growing tissues of the two unite, resulting in the growth of the dormant bud, or buds. It has been found already that the region of the passage of food-materials upwards and of the elaborated sap downwards in the plant is that part where the bark and the wood unite. Just between these layers is the part of the plant where growth in thickness takes place most actively; in fact, it increases by the addition of wood on its inner surface and bark on its outer. It is called the **cambium layer**, and for the sake of brevity will thus be spoken of when mentioned.

Plants in their natural state are constantly in danger of injury to their bark, injury which results in much loss of moisture by evaporation. We have found already that, just before the fall of its leaves, the plant closes up, by the development of a corky layer, the passages by which moisture ascends to the leaves from the stem, thus preventing loss of moisture in winter. We need not be surprised then to find that any injury to the bark of the tree is almost immediately followed by an attempt on the part of the plant to heal up the wound and prevent loss of moisture. A few years after a large branch has been cut from a beech tree, this healing up of the tissues over the region up and down which the sap passes is quite evident. It can also be seen in a less degree in the bases of cuttings of currants which have successfully rooted. In each case this healing over of the moisture-containing tissues is the work of the cambium, which by the development of new wood on its inner surface and new bark on its outer, strives to close the means of escape for the sap. This healing is one of the most natural processes in nature, and upon it depends wholly the success of budding and grafting.

Contact of cambium-layers.—We found that seed production depends upon the union of two cells, one from the pollen of one flower and one in the ovary of another. Sometimes these cells have their origin in the same flower, but more often they develop on different plants, one cell being carried to the other by insects, wind, etc., in the form of pollen. Now when we consider that two distinct cells from different plants have the power of uniting and producing a seed which will develop into a new plant, it need not be a matter of wonder that similar cells of plants will unite if placed in favourable circumstances, especially as we have found that the tendency of a plant is to form a healing layer over any wound made.

When the two living cambium layers are placed in contact, each begins to form new wood on the inside and new bark on the outside, and in the process similar tissues of the layers unite. In many cases this union is so perfect that if, after a time, a cross section of the junction be made and placed under the low power of a microscope, no evidences remain to show where the stock ends and the scion begins. Of course, should contact not be close all over, such complete union does not take place, and a weak spot in the wood is apt to be the result.

Prevention of evaporation.—In the case of budding, the overlap of the lips of the wound in the stock is sufficient to prevent loss of moisture by evaporation, but no such covering exists in most forms of grafting. Therefore some covering must be given to the wounds, or the tissue of the scion will be subjected to the loss of so much moisture that it will dry up and die.

Grafting wax may be obtained with which the whole of the junction must be smeared carefully. Should the student prefer to use a mixture of his own making, the following makes as good a wax as any: 4 lb. resin, 2 lb. beeswax, and 1 lb. tallow, melted together, poured into cold water and worked with the hands until it is as white as possible. The application of this mixture effectively prevents evaporation, and at the same time refuses entry to rain, which might cause rotting.

16. Whip- or tongue-grafting.—Choose another piece of sycamore, or of any other suitable tree, and treat exactly as in the case of splice-grafting, so that the pieces when placed together form one straight rod.

Now place aside the top part, or scion. Take the bottom part, or stock, in the left hand with the cut surface facing you, holding the piece by the tip of the cut surface, the base being pressed against your chest. Place the edge of the knife-blade square across the cut surface at a point about one-third of the length of the surface away from the tip, and cut downwards with the grain of the wood for a distance of about three-quarters of an inch (Fig. 64, *e*). Be careful not to split the wood.

Take the top piece. Hold it also by the tip of the cut surface, and cut downwards for the same distance from a point one-third of the length of the cut surface away from the tip, taking care not to split the wood (Fig. 64, *d*).

Place the surfaces together so that the beginning of the longitudinal cuts are at the same point, enter the tongue of the base part into the longitudinal cut in the upper part, the tongue of the upper into the similar cut in the base, and push the pieces home until the tip of each cut rests exactly upon the base of the other (Fig. 64, *e*). Tie together with raffia, or bast.

When and why to graft.—It has been considered wise, and has been found profitable in practice, to insist upon the student's having several opportunities of forming grafts on the branches of forest trees before he attempts the operation upon the fruit trees in the school-garden. Grafting is an art in which proficiency can be attained only by practice, and not one, but many attempts, must be made by the student upon waste pieces of branches ere he performs the actual operation in the garden. The period of school life, too, is so short that rarely does a student see the full results of this operation; so that he is really acquiring knowledge and experience which he hopes to have opportunity of putting to further use later, when he can year after year watch the results of grafting on the trees in his home-garden. Sufficient proficiency, however, can be attained easily in his first year of school garden-work to enable him to insert one graft upon a tree, and watch the results during the remaining years of his school life.

It may be allowed at once, however, that nurserymen as a rule are averse to selling ungrafted stocks which pay so much better after grafting. The garden-worker may then of necessity have to work on rooted cuttings, or on stocks grown from seeds by the students of previous years. If these are obtainable they should be used, but the student should make a point of planting or sowing at least three cuttings, or seeds, to make up for each stock he uses. As a rule, however, whip-grafting may be practised upon the branches of a standard tree grown for the purpose. Also if some crab apple, plum, wild cherry, etc., trees be grown in the protective border, no opportunity of attempting experiments upon these should be missed. There is thus little necessity for the mutilation and destruction of the ordinary crop-bearing trees of the garden for the sake of practice.

Inter-relations of stock and scion.—The student, in choosing both stock and scion, must keep in view the fact that grafting does not result in a simple union of these two parts. That close union of the tissues in many cases does take place is indubitable, but it must be remembered that each part retains its former physiological characteristics, *i.e.* if the stock be originally dwarf, the flow of sap will still be weak after grafting; if a strong grower, the flow will be strong. In the same way, if the plant from which the scion is taken be of dwarf form, the manufacture of food in the leaves will be comparatively small compared with what it is in the case of a scion from a free-growing plant.

Not only do these parts retain their characteristics, but they also interact upon each other. Thus the physiological changes and the structure of the stock regulate how much, or how little, moisture from the roots shall pass upwards to the scion; while the nature of the scion on the other hand determines how much, or how little, manufactured food the stock will receive for the building up of the tissues of its stem and roots. Or, again, the healing of the wound of the graft may be such that the inter-relations of the scion and the stock are modified by mechanical causes, such, for instance, as the stoppage of the flow upwards or downwards by a defective union. It is thus evident that the result of grafting must not be looked upon as mere union of the cambiums of stock and scion, but that by this union many unlooked-for changes may appear in the character and growth of the resulting plant if it be compared with either of its parents.

CORRELATED EXERCISES.

1. Which class of plants, *i.e.* annuals, biennials, or perennials, is made most use of for the food of man in the warm-temperate and cool-temperate regions of the world? Can you account for this?

2. Explain how it is possible to grow the vine in this country, a plant which naturally belongs to the Mediterranean climate. Describe clearly how an approximation to the necessary climatic conditions is produced.

3. Account for the wilting of the leaves of young plants which have been transplanted in bright sunny weather.

4. Describe exactly how you would increase your stock of strawberry plants from those you have in the garden.

5. Dig up a year-old black-currant, or gooseberry, cutting and describe carefully what you see.

6. Explain how a plant heals a wound made in its bark. Why is such healing necessary for the healthy development of the plant?

7. Examine the trees in the vicinity, looking for cases where large branches have been cut from the growing tree. Can you find a case where such pruning has been done carelessly and a large splinter of wood has been torn from the piece of branch left? Find another where no such injury had been done. Examine the result of healing in each case, and describe what you see.

8. Why is a fruit-tree grafted?

9. Describe how a union is effected between the stock and the scion of a grafted tree.

10. What factors help to determine the type of growth which will be made by the scion after it is grafted?

11. Examine any plants you see growing in gardens on which an uncommon combination of plants has been made by grafting, *e.g.* apple on pear, etc. What results do you note upon the fruit produced? Attempt some such combination upon one of the trees in the protective border around your garden, and note results.

12. Bud a rose upon a stock grown from a cutting of a dwarf-growing briar. Describe the result with regard to the character of plant, type of growth, size, and period of bloom.

13. Account for the fact that the temperature of the air inside a cold frame is higher than that outside, and that this enclosed air is moister than the surrounding atmosphere.

14. Cut a potato into two pieces. Note the soft substance exposed. Describe it. Leave the pieces in the garden-shed over night. Again examine the surfaces. Describe the corky covering which has been formed. Associate this with the tendency of all plants to heal up a wound made in their tissues.

CHAPTER X.

ORGANISMS IN THE SOIL.

1. Life in the soil.—Dig up a spadeful or two of earth. Carefully separate the soil with the fingers, picking out everything which shows signs of life and placing each in a box. Some are very deceptive in appearance, and may appear to be lifeless until they are pressed. Name all those you can, and attempt to find out what the others are by enquiring. If you have dug up any grubs and chrysalides, place them in a breeding box along with some soil and fibrous roots, and watch their development.

Dwellers in the soil.—The soil is too often regarded as purely dead matter; indeed, even the experienced gardener can hardly be brought to view it in any other light than this, but very little examination will show the student that he dare not take this narrow view if he is to grow plants intelligently. A little attention to a few spadefuls will at least convince him that the soil is a world in itself, having its own inhabitants who live in close association with each other, whose bodies are so constructed, and organs so arranged, that they are suited specially to the environment in which they have existence.

Also, when by a marvellous and inexplicable process, some of the seemingly lifeless bodies by and by change, take to themselves wings and a different body, and fly away into the atmosphere, the student cannot help realising that the earth is a hatching-ground for many of the organisms whose existence he has always associated with the world above-ground. And when certain of the underground dwellers leave their haunts and invade the atmospheric world, dealing havoc among young growing shoots, little argument is necessary to persuade the garden-worker that the inhabitants of the soil are worthy of at least some attention from him. To some of these it is scarcely necessary to refer.

Moles are especially attracted to garden ground on account of the enormous number of earth-worms found there as a result of intensive cultivation, and a few days' experience of the wanderings of one of these animals is more than sufficient to convince one of the need of a mole trap. The purchase of a trap is a simple matter; the difficulty arises when the mole refuses to enter; and, wits being matched against instinct, it is really astonishing how often the latter wins.

Mice are very destructive to young seedlings and soft shoots on young fruit trees grown on walls. A trap is the only remedy.

Slugs are cosmopolitan in their tastes. Young cabbage leaves, lettuce plants just when they are most toothsome, sweet-peas gloried in as the "first-up" in the whole neighbourhood, the first carefully-nursed strawberry of the year—each in turn is found out and destroyed, unless the destroyer be caught in time. The most effective method is the organisation of a slug hunt during a shower and the removal of all hiding-places for them.

Earwigs are especially fond of young shoots of dahlias, etc., and they also must be trapped. Crumpled pieces of paper laid at the base of a plant, or a flower-pot containing some dry grass placed bottom up on the top of a plant-stake, provide pleasant hiding-places for them—until the garden-worker comes along in the morning.

Grubs and chrysalides.—Many insects, moths, etc., lay their eggs in the soil just beside the stem of a plant, or often actually in the stem itself. The result is that three different stages of insect life are to be found in the soil, *egg*, *larva* (commonly termed *grub*, *maggot*, or *caterpillar*), and *chrysalis*. Many of these are so small that hundreds may exist in a spadeful of soil and escape all but the closest observation, while others are evidently doing harm to plants by feeding on roots and stem. They must be considered individually when it comes to their destruction, but generally speaking *vaporite* at the rate of one pound to ten square yards will clean the land. In digging the soil, all grubs turned up should be ruthlessly destroyed.

2. Earthworms.—Take a box about 9 inches deep, the bottom of which is not nailed on, but kept in position with string. Fill to within a couple of inches of the top with garden soil to which are added a couple of dozen or so earthworms. Keep the soil moist and feed the worms by placing pieces of plant remains, roots, leaves, etc., on the surface. Note how these disappear. What happens to them? Examine worm casts on the surface. After a fortnight, remove the bottom, and place the box outside, resting on the ground to dry. Remove the wooden sides after the earth is quite dry. Note the burrows made by the worms. Of what benefit are these to the soil?

The work of earthworms.—Even to-day it is to be feared that there are people who believe that worms work much harm to the roots of plants, and who never lose an opportunity of reducing the number of earthworms in their garden soil. The idea is erroneous and the action ill-advised. The good done by worms much more than counterbalances whatever little damage they do. In fact we owe the fineness of the surface layer of mould containing much decayed vegetable matter almost wholly to earthworms, a point which no garden-worker dare overlook in the production of a good seed-bed.

Elaborate investigations in this direction were carried out by Darwin, who calculated that practically the whole of the finer particles in the surface ten inches of soil pass through the gizzard of worms in the course of fifty years. They pass this soil through their bodies for the sake of the decayed organic matter which it contains, and from it worms extract the food-material. But along with this organic matter many particles of soil are swallowed and in the gizzard of the worm these are much rubbed together, and made finer. The particles pass away as excreta, the fineness of which is specially noticeable in the "worm-casts" upon the surface of a lawn. When it is considered how many worms must exist in a cubic yard of garden soil, and how many ages they have been at work, it is evident that the whole of the finer mould of the surface soil must have passed through them several times.

In addition, worms are valuable as a means of opening up the soil and aerating it. Down the burrows which they make, sometimes to the depth of four to five feet, air and rain-water find their way, and the importance of these has been insisted upon too often already to need repetition here.

3. **Plant roots.**—Carefully dig up the root-remains of a pea, or of an annual flowering plant the stem of which has to be cleared off the ground. Note the enormous amount of rootage left behind in the soil. Of what substances are the roots composed? Are they of any use to the soil?

Vegetable remains in the soil.—When organisms in the soil are spoken of, not merely those which possess animal life are included. All living matter comes under this heading, and the roots of plants must not be omitted. The plant leaves behind in the soil a dense mass of roots and rootlets, and these contain much organic matter, which in the process of decay gives rise to **humus.** This humus, or decayed vegetable matter, contains a large store of nitrogen which may by and by find its way to the crop as food-material. This supply of humus is not, as with farmyard manure, confined to the surface layers; the roots penetrate much deeper than manure is usually laid in the soil, so that the roots of the succeeding crop find a store of food-material ready for them as they push their way downwards.

Just as in the case of the burrowing of earthworms, the decay of plant-roots increases the aeration of the soil. As roots decay they leave behind them spaces which permit freer entrance of air and a greater supply of oxygen.

4. **Bacteria in the soil.**—On p. 8 we saw that even in the soil from which all living organisms visible to the naked eye have been removed, there must be some form of life existing. It was found that oxygen was used up and carbon dioxide evolved—a sure sign that oxidation or burning was going on, and when burning is slow and flameless, as it was in this case, it is often due to the presence of some living organism.

Take some milk which has been boiled in a Florence flask for about half an hour; plug the flask with cotton wool, and allow to cool. Introduce a little garden soil, plug, and leave for some twenty-four hours in a dark cupboard. Take out, smell, place a drop under the high power of a microscope, and examine. Distinguish small bodies moving to and fro in the liquid. These forms could not have existed in the milk used, for it had been boiled sufficiently long to kill any such organisms. They could not have entrance from the atmosphere, for the cotton wool resists their passage. Whence must they have come?

The surface layers of garden soil are teeming with microscopic life (Fig. 65); in fact a handful of soil contains hundreds of thousands of these **micro-organisms.** This seems incredible, but if Expt. 4 be performed a few times, the well-nigh uncountable numbers found in one drop of the liquid brings home the fact that "hundreds of thousands" may after all be under-estimating the number. But what is wanted here is to insist upon the fact that the soil is not dead matter by any means; it teems with life, life so small that the organisms are not visible to the naked eye; but insomuch as they are living, they must be taken into consideration in connection with the working of the soil and the growth of plants.

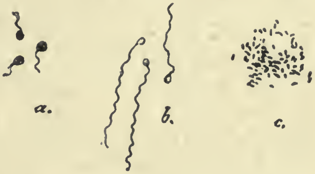


FIG. 65.—Different forms of soil-bacteria.

Kinds of bacteria.—These living organisms are called **bacteria.** They are found in greatest abundance in the surface layers of the soil, and decrease rapidly in numbers as the subsoil is reached. They are not by any means all of one kind (Fig. 65), nor are their functions similar; and different kinds have different effects upon soil constituents. But they may be divided generally into two kinds—those which require the presence of oxygen if they are to live and work freely; and those able to proceed with their development and work in the absence of oxygen.

Fortunately, too, those bacteria which need oxygen are on the whole those which are beneficial to the garden in their effects; the others may be regarded generally as harmful. So that more or less harmful bacteria will find suitable environment and crowd out the useful bacteria in such ground as is not freely aerated, *e.g.* marshy land, badly drained soil and subsoil. Useful bacteria will predominate in what we usually consider good garden ground. The action of harmful bacteria we need not consider, but the effects of useful bacteria are sufficiently important to deserve some little consideration.

The conditions under which useful bacteria work.—It has been found already that useful bacteria require the presence of oxygen for their development, and therefore the conditions already spoken of as affecting the aeration of the soil have an influence upon its bacterial life. But even with the free passage of air, these organisms do not always work. In several cases the fact that life usually has a period during which it remains dormant, or asleep, has been noted already; and bacteria are no exceptions to the rule. During cold weather their development is suspended, and they enter the dormant or spore stage, only waking up to activity when the temperature of the soil reaches the degree which suits their development. Neither do they work in an absolutely dry soil. This can be seen easily by allowing the drop of liquid under the microscope to evaporate, when it will be noticed that the bacteria show no signs of life, and in many cases change their form even to suit their altered conditions. These absolutely dry conditions practically never occur, however, in ordinary garden soil.

The work of bacteria.—No organism can exist without giving off excreta of some kind during its life, and leaving remains in some form when it dies. There is well-founded belief that as a plant grows it gives rise to certain excreta which pass away by means of the roots; and that it leaves behind it remains in the form of roots and cast-off leaves is obvious to all. Now the accumulation of these excreta and remains would soon result in there being no room in the soil for any crop to grow, that is unless they decayed and became part of the soil (or passed off into the atmosphere). This decay would not take place, or at most would proceed very slowly indeed, were it not for the action of bacteria, and here we have the first marked benefit of their presence in the soil.

Bacteria and plant remains.—At the outset it must be understood that "plant remains" and "humus" are not one and the same thing. The former may in all probability become changed by and by into the latter, but this change is the result of bacterial action and will be discussed first. During the life of a plant it is busy building up plant tissue, to the composition of which go organic compounds which are themselves composed of carbon, nitrogen, hydrogen, oxygen, and different mineral substances derived from the soil. Now it has been found already that bacteria require oxygen for free development, just as animals do. But the using up of oxygen implies burning of some kind, and burning cannot proceed without fuel.

Man and animals use the organic compounds found in the composition of plants largely as fuel, and it is these same organic compounds which bacteria seize upon and use in the process of oxidation. This oxidation or burning provides energy which keeps in progress their machinery, *i.e.* their bodies (if so microscopic an organism may be dignified by such a name). The result, just as in the case of all burning, is the evolving of carbon dioxide which passes off through the soil to the atmosphere. This process disposes of the carbon in the plant-remains. The nitrogen, of which practically the whole soil supply is derived from plant-remains, is at the same time let loose. The result of the action may be regarded as the dark-brown substance known as humus.

Bacteria and the supply of nitrogen.—Although these different actions are dealt with here in turn, it must be remembered that as they are the result of the activity of different sets of bacteria they may all be regarded as proceeding simultaneously. The highly specialised actions of these soil organisms become very noticeable when the extraction of nitrogen from humus is examined. It has been found that one set converts nitrogen into ammonia, another the ammonia into nitrites, and a third the nitrites into nitrates. Thus, in order to render the nitrogen contained in humus soluble in water and so usable for plants, at least three different sets of organisms act upon it, any one of which is unable to perform the work of the other, while each is dependent upon the other for existence. Consequently the sole supply of nitrogen for plants, save those of the pea-family, is that extracted from the humus of the soil by the action of bacteria.

It has been noticed already how the pea-family—by means of nodule-forming bacteria—is able to make use of the free nitrogen of the air ; so that the whole supply of nitrogen, the most necessary element for the full development of any plant, is obtained wholly by bacterial action.

Bacteria and soil-minerals.—Directly, of course, bacteria have no influence upon the mineral substances present in the soil. These are not used in the process of oxidation. But indirectly the influence of bacteria is great. In the process of oxidation the carbon existing in the compounds of plant-remains is given off as carbon-dioxide. Now several minerals of importance in plant-growth, carbonate of lime, for example, are practically insoluble in pure water, but not so in a solution of carbon-dioxide.

The result is that carbonate of lime is thus rendered soluble, and is used up as food-material when carbon dioxide is evolved by bacterial action, and the greater the amount of plant-remains, farmyard manure, etc., applied, the more carbon dioxide is evolved and the greater is the loss of carbonate of lime to the soil. It is evident, therefore, that by constant application of farmyard manure the soil supply of lime becomes used up, and the soil tends by and by not only to be deficient in lime, but to become acid. Therefore the necessity of occasional liming in the case of a garden receiving yearly large supplies of farm manure is manifest.

The formation of carbon dioxide seems also to have a somewhat similar effect upon other minerals which are of importance as food-materials for the plant.. They are rendered soluble, and therefore available for the use of the plant.

Fungi, etc.—Here, too, might be discussed the fungi which exist on and in the garden soil, together with the different forms of insect life, viz. egg, larva (commonly known as caterpillar, grub or maggot), and chrysalis, which the garden-worker turns over as he digs. All these, however, must receive attention in detail when the subject of plant diseases is being dealt with, so that it has been considered better merely to refer to them here, leaving details to be discussed later.

Lessons for the garden-worker.—While much pleasure and interest may be found in the pursuit of knowledge in connection with soil and plant life, yet it is when this acquired knowledge is put to practical application that its full benefits are experienced. The utilitarian aspects of the results of scientific inquiry must not be omitted by the garden-worker, and in connection with the study of bacterial action he will find at least a few points which he may make use of in plant-growth and soil-working. Several of these are summed up in the following sections.

Bacteria, save in the case of those found in the roots of the pea-family, add no new plant food-material to the soil. This is the business of the garden-worker. What bacteria do is to render available for the use of the crop such materials as already exist in the soil. And without their action the supply of food-materials could not be maintained by the soil, so that for bountiful crops and the continued fertility of his ground the garden-worker is almost wholly dependent upon the activity of these micro-organisms. That is, without their action the fertility of the soil would cease.

This being the case, it is the business of the gardener to see to it that the physical conditions of his soil approach as nearly as possible those required by bacteria for their full development. They are not active in very wet soil which is impervious to air, so garden ground must be well drained. Free action proceeds only when the soil is at a certain temperature, and the rise in temperature is connected very closely with the darkness of the soil. An increase of dark colouring matter will therefore as a rule be associated with quick warming and earliness of bacterial action. This can be secured best by increasing the amount of decayed organic matter in the soil.

In cold springs, the growth of vegetation sometimes comes to a standstill. This is due to the fact that owing to reduced temperature bacterial action is suspended, and as a rule a deficiency of nitrogen is experienced which may result in a poor plant later. The garden-worker should step in here, supplying food-material by means of liquid manure poured in at the roots of those plants which show signs of being backward. Thus he is able to carry the crop over the period of shortage of supply, and the application of liquid manure may become less frequent as the temperature rises.

It has been remarked that the turnip crop in good soil does not require the application of nitrogenous manures when once it is past the danger of the flea-beetle attack. Yet nitrogen is being used up, and that in large quantities, for an average crop is found to contain about 100 pounds of nitrogen per acre. This nitrogen is mostly derived from the humus of the soil, and is let loose as the result of bacterial action. Now turnips in the field permit of much working of machines between the rows, resulting in much loosening and free aeration of the soil, together with distribution of the bacteria.

This working both thoroughly aerates the soil and at the same time results in a rise in its temperature owing to the dryness of the surface layer—well nigh perfect conditions for bacterial action. So that the more working there is of the surface by hoeing, etc., the greater is the activity of soil-bacteria, and as a result the greater is the amount of nitrogen, etc., made soluble for the use of plants, with consequent greater growth and a better developed plant all round. In fact, there are few better ways of furthering the growth of a good plant in any crop than thorough and frequent hoeing of the surface soil.

Finally, bacterial action sets free the carbon dioxide in the soil, and this gas in solution with water acts upon the carbonate of lime present, rendering it soluble, and thus bringing it into a condition in which it is suitable for plant use. Thus increased bacterial action results in decreased lime-supply in the soil. This is most marked when ground has been treated steadily with farmyard manure for years, no other fertiliser being applied. The growth of moulds on the surface of the soil is common, "finger-and-toe" puts in an appearance in cabbage and turnips, crops are poor, the manure which is applied does not thoroughly decay on account of the fact that the soil is too acid to allow of bacterial action, and matters are not set right until the land has been well limed. This liming reduces the acidity, restores bacterial action, and supplies the soil with the lime which it requires for the full growth of plants.

CORRELATED EXERCISES.

1. Describe in detail the work of earthworms in garden soil.

2. Describe the life history of the common cabbage-butterfly.

3. How do bacteria help to rid the soil of plant-remains which would otherwise prevent the growth of future crops?

4. By what means do bacteria help to provide the supply of nitrogen necessary for plant growth?

5. Show how the action of bacteria helps to cause decrease of the lime-content of the soil.

CHAPTER XI.

RAW FOOD-MATERIAL SUPPLIED TO THE SOIL IN THE FORM OF MANURE.

1. The substances of which a plant is composed.—Take a piece of potato tuber, potato stem, turnip, pea-stalk, etc. ; weigh as soon as cut, record the weight, and lay each in a porcelain dish ; then place in a warm oven for some hours. When all the water has been expelled and the remainder seems quite dry, weigh again. Record. What has caused this difference in weight? Now place each in an evaporating dish and subject to the heat of a bunsen flame, taking care that no sparking is allowed, or something may be lost. When cool, weigh again and record. Certain substances must have passed away to occasion this second decrease in weight. In what form must they have been lost? Weigh the remainder and record.

Organic and inorganic constituents.—If an average living plant be taken and dried, by far the greater part will be found to consist of water, and of the dry part left some is evidently complex in character, for much of it departs as *gas* upon being subjected to further heat. A much smaller quantity remains behind as *ash.* Of the latter two, the gaseous part represents the manufactured food which the plant has elaborated in its leaves. The ash remaining represents a small amount of raw food-material which the plant has derived from the soil, and is either as yet unused or has already been built up into plant tissue. The former are called **organic** matter, the latter **inorganic**. If these names are examined very carefully their aptness will be specially noticeable. An ordinary potato plant will be found to contain these materials in about the following proportions :

Potato plant.

Water.	Dry matter.	
80%	20%	
derived from soil.	Combustible matter.	Ash.
	19% from air.	1% from soil.

Now certain of these substances, viz. water and carbon dioxide, we have already accounted for, but of the ash constituents we as yet know nothing save that much of it must have been derived from the soil-moisture.

2. **Elements present in solution in soil-water.**—Take a flower-pot, place several layers of filter paper over the hole, fill up with garden soil, and pour water in at the surface. Catch the water which drips from the hole in a dish, and continue doing this until a good deal is collected. Now filter this water again, and then place some of it in an evaporating dish and apply gentle heat. Add more water from the dish as evaporation proceeds. When this has been done for some little time, what do you note gathering on the sides of the evaporating dish? Collect it and examine.

Inorganic matter in the soil.—We have now collected some of the substances existing in solution in soil-moisture, but further it is impossible for us to proceed with our elementary methods of investigation. Chemists have found that this fine brownish powder, which usually amounts to but 0·01 to 0·03 per cent. of the soil, is not all of the same composition; in fact, quite a host of different chemical compounds are here represented.

A field in Rothamsted which had been unmanured for fifty years showed the inorganic substances tabulated on p. 195 in the given quantities. This means that 0·27 per cent. of the ash part of the soil consisted of potash, and there were altogether in an acre of this land, calculating the soil to the depth of 9 inches, 6750 lb. of potash. The amounts of the other substances were found in most cases also to run to several thousands of pounds. These names and figures are not given for the student to memorise, but are included for reference and for a purpose which will presently reveal itself. It may be stated that the ash which remains when a plant is burned has been found to contain most, and in some cases, practically all the substances above mentioned. That is, the substances in solution in soil-moisture are for the most part the very substances which form the ash constituents of plants.

Substance.	Per cent.	Lb. per acre, taking the soil as 9 inches deep.
		lb.
Soda	0·06	1,500
Potash	0·27	6,750
Magnesia	0·36	9,000
Lime	2·49	62,250
Alumina	4·49	112,250
Oxide of iron	3·40	85,000
Phosphoric acid	0·11	2,750
Sulphuric acid	0·05	1,250
Carbonic acid	1·30	32,500

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Water-culture.—Are all these substances necessary for the full growth of plants, or can the plant grow well wanting some of them? By growing plants by the method of **water-culture**, *i.e.* not in the soil but with their roots dipping into water containing food-materials in solution (Fig. 69), this question can be answered. One plant is grown in a solution containing all the above substances, in the next solution one substance is omitted, in the next another, and so on, one different substance being omitted in each case. By this method it is found that practically all these substances are of sufficient importance to the plant to render its growth markedly less if even one be omitted.

Field experiments.—This result would suggest that if a manure be applied to a piece of garden ground, all the above materials must enter into its composition; but experiments in the growth of crops in field and garden have shown that the soil is always able to provide a plentiful available supply of most of them, and only two of them are liable to be used up by the plant at a greater rate than the soil can supply them in a soluble form, namely, **phosphoric acid** and **potash**. So that to make good the loss of the inorganic substances mentioned above, manures composed mainly of phosphates and potash are needed.

Organic matter in the soil.—On p. 29 we dealt with a part of the soil not yet examined in this connection, *i.e.* that which is combustible. The percentage will be found to vary very much, from perhaps 10 per cent. in a field close to the garden to 20 per cent. in the garden itself, and perhaps 50 per cent. if the soil has been taken where leaves have been allowed to decay year after year. This fact leads to the supposition that this combustible part is really leaf, root, twig, etc., remains of plants which have fallen on to the soil or been dug in and have there decayed; and this is correct.

When this humus was driven from the soil by burning, the colour was found to be changed, so that we may judge that the dark colour of the soil is due to the presence of humus.

Now by simple methods of examination we are unable to proceed further; analysis of the humus has shown that it contains important elements which are found in the composition of plants, and part of the 19 per cent. of combustible matter already spoken of in connection with the analysis of the potato plant. The most important of these elements is **nitrogen**, and in the Rothamsted field, particulars of whose soil have been tabulated already, 0·1 per cent. of nitrogen was found, equal to 2500 lb. per acre, taking the soil all over at a depth of 9 inches. This nitrogen is generally the only other constituent of which the soil is apt to be depleted by the growth of plants, and which the ground is not of itself capable of renewing in a soluble condition at a rate sufficient to answer the plant's requirements.

Available and non-available food-materials in soil.—But when one turns to find what quantities of these three substances, nitrogen, phosphorus, and potash, already exist in the soil, the figures are so amazing as to lead to the thought that it must be almost impossible for the supply to run short. In the unmanured Rothamsted field were found per acre 2500 lb. of nitrogen, 2750 lb. of phosphorus, and 6750 lb. of potash, and if the following table be examined it will be found that crops do not withdraw even a tithe of the above amounts each year.

Indeed, were all the above food-materials available for plants, *i.e.* in a soluble condition, the soil contains sufficient food-materials to grow a hundred crops. But as we have found, the plant can make use only of those substances which are in solution, and but a small proportion of each of the above quantities answers this description. This explains how a marked increase in growth is noticeable as a result of the application of a comparatively small quantity of readily soluble manure to the plant. The insoluble materials are each year being rendered soluble by bacterial action, and also by the action of air, water, frost, etc., when the ground is rough-dug for winter, but only a very small proportion of the mineral matters thus becomes available for the crop each year.

Proportion of the three chief soil constituents contained in various crops. Pounds per acre for average crop.

Crop.	Nitrogen.	Potash.	Phosphoric acid.
Beans - - -	107	67	29
Cabbage - - -	114	129	33
Carrots - - -	48	153	27
Onions - - -	32	23	9
Potatoes (tubers only)	46	76	22
Parsnips - - - -	66	186	57
Strawberries - -	9	10	4
Turnips - - -	110	148	33
Wheat - - -	50	29	21

3. Necessity for manuring the soil.—Fill two large-sized flower-pots with soil taken from the same part of the garden. Place both in a cold frame in early spring. In *A* sow some mustard seed ; leave *B* without any crop. As the seeds grow, supply both pots with plenty of water, but carefully remove all signs of growth of weeds from *B*. Water the mustard plants until they are fully grown, still removing all weeds from *B* as they appear. When the plants have set in fruit, carefully remove them, pulling up roots as well, but taking away no soil.

Now you have two pots of earth *A* and *B*. *A* has grown a crop of mustard plants ; on *B* no crop has been grown.

Sow mustard seeds in each of the pots, that is, grow a second crop in *A* and a first crop in *B*. Sink the pots in the open soil to within an inch of the rim, water equally, thin out each crop to ten or so of the best plants, retaining the same number in each, and note the result in crop when the plants have grown to their full size.

Fig. 66 shows the result of growing a second crop of mustard in the soil of pots Nos. 1, 3, and 17, each of which had previously borne a crop of the same plant. The soils were kept in the exact condition in which they were left by the first crop (Figs. 4 and 17). If the first and second crops as shown by these photographs be examined, a marked difference will be noted. The first crop grown is heavier and stronger than the second in each case. This points to the necessity of treating the soil in some way during the period between croppings if the yield is to be maintained.

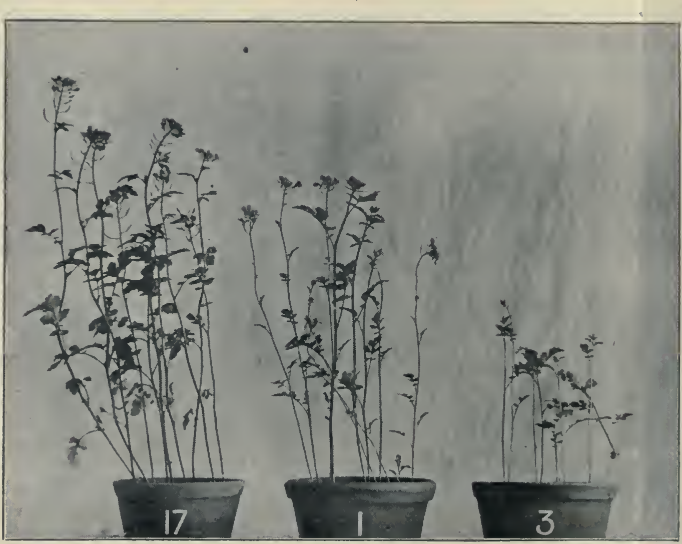


Photo Mr H James.

FIG. 66.—A second crop grown on the same soil without manure.

Manuring the soil.—This fact was realised early in the history of agriculture, and naturally what first suggested itself was that the land should be stirred and thoroughly dug-up. This, indeed, was called manuring the soil (French manœuvrer = to work with the hand), and even in the seventeenth century we find the word manuring used with this meaning. But by and by it became evident that more than mere working of the soil was necessary, and with this knowledge began early attempts at scientific manuring.

Manures are necessary largely because certain substances have been removed from the land by the growing crop, and the crop itself has been removed from the land by man. Thus the soil is steadily losing certain substances ; and by this loss man and animals are steadily gaining, as the energy which plants have acquired from materials taken from the soil and the air and have built up by energy derived from sunlight, man and animals appropriate for the building up of their own tissues, and thus for the sustaining of their own energy. The soil is consequently steadily losing its fertility, and the food-materials taken from the soil must be replenished by manuring if good crops are to be grown.

Farmyard manure. Composition.—Farmyard manure, or dung, is used so commonly in the growth of crops that it must take first place in our consideration of manures. It consists of solid and liquid excreta of animals, usually of the horse, cow, or pig, together with the litter used as bedding. Seeing that vegetable matters form the chief food of these animals, their excreta must contain practically all the substances we have already found the plant to contain, but the proportion will differ in the case of the excreta, inasmuch as certain substances in the food have been retained by the animal for the building up or working of its own machine, its body.

The food eaten by an animal, in coming under the action of the several digestive organs, is acted upon in such a way that much of it becomes broken down into soluble compounds and is taken up by the blood. Sooner or later a large part of these passes from the blood and is excreted in the urine. Other parts of the food are more or less indigestible, *i.e.* resist the action of the digestive organs, and pass through the animal in an unchanged form. These are excreted as solid matter. Thus the solid excreta represent substances which have withstood already the processes of the digestive organs, and are therefore not readily soluble, while the liquid contains in solution substances which, if not quite ready to be used as food-material by the plant, need but little change ere they are brought to this condition.

4. Chemical composition.—Obtain a small piece of horse manure, as fresh as possible. Weigh an evaporating dish. In the dish weigh out about 5 grams of the fresh manure. Place the dish containing the manure on a sand-bath and apply heat until all moisture is evaporated. Allow to cool. Weigh and record. Now subject the air-dry manure still in the evaporating dish to the heat of a bunsen flame until only red ash remains. Allow to cool, weigh and record. Subtract the weight of the dish from the weight of dish + ash.

Tabulate as follows:

	Grams.		Grams.
Dish + fresh manure	=46·93	Dish + air-dry manure	=43·31
Dish	=41·93	Dish + ash	=42·04
Fresh manure	= 5	Burns away, *i.e.* organic matter	= 1·27 = 25·4%
Dish + fresh manure	=46·93	Dish + ash	=42·04
Dish + air-dry manure	=43·31	Dish	=41·93
Moisture	= 3·62 = 72·4%	Ash, *i.e.* inorganic matter	= 0·11 = 2·2%

The above result gives a rather low percentage of moisture, as the manure was not quite fresh, but is sufficiently accurate to impress the main facts upon the student.

Chemical composition.—Water is the largest component of both liquid and solid excreta. Even of the latter it forms, on an average, 86 per cent. in the case of cow manure, and 75 per cent. in the case of horse manure, when each is in a fresh condition and unmixed with litter. This leaves but a small fraction of the whole which may contain food-material, and, in fact, whether cow or horse manure be considered, but a small part of this fraction is composed of nitrogen, phosphoric acid, or potash – the three substances we have found already it is necessary to supply to the soil in the form of manure. As a matter of fact, the percentage of either of these in the whole mass seldom rises to 1 per cent. in fresh manure without litter, while only a trace is found in some cases, and yet so small a quantity as this in an available form gives a marked increase in crop.

As a substance containing raw food-material, farmyard manure is most valuable for the supply of nitrogen it contains, for though a certain amount of potash is present, the manure is comparatively lacking in phosphoric acid. On this account it cannot be viewed as a well-balanced manure, and the use of some other fertiliser in addition is therefore advisable.

Lasting effect of farmyard manure as a supplier of food-materials.—But farmyard manure as used on field and garden is mixed with litter, and the straw of the litter being part of a plant, contains in its composition nitrogen, phosphoric acid, and potash in appreciable quantities amounting to as much as 0·5 per cent. of nitrogen, 0·2 per cent. of phosphoric acid, and 1 per cent. of potash. Here, then, is a manure having in its composition the three substances which the soil requires for the production of good crops, and these substances are not all at the same stage of solubility. The contents of the urine are readily available, as has been seen already, and the plant can make use of them soon after application, while in the solid excreta and the litter are substances which must be subjected to changes—bacterial and chemical for the most part—ere they can be utilised by the plant. Thus farmyard manure is very lasting, as a supplier of the raw food-material, its effects extending sometimes over several years.

Physical effect on soil.—The importance of humus, or decayed organic matter, as a source of nitrogen in the soil has been seen already, and up to a certain point the more humus in the soil the greater is its fertility. Now the decay of the organic matter in farmyard manure causes a steady increase in the humus content of the soil. This can be seen easily even by comparing the colour of garden soil and of that from an adjoining field. The former is darker, and this is wholly due to the heavier application of farmyard manure it receives.

5. **Effect on moisture-content.**—Farmyard manure also has an important effect on that most important feature of garden work, the moisture supply. From two plots at Rothamsted, one dunged and one left undunged, samples of the soil were taken at different depths and tested for moisture. On the previous day 0·26 inch of rain had

fallen, but for nine days before there had been little or no rain. The results were as follows :

Depth.	Unmanured plot. Per cent. moisture.	Manured plot. Per cent. moisture.
0– 9 inches.	16	19·3
9–18 „	19·8	17·0
18–27 „	23·3	18·4

By permission of Mr. A. D. Hall, F.R.S.

From the above table it is evident that the surface 9 inches of the plot which had been treated with farmyard manure retained considerably more moisture than the surface of that which had received no manure. The rain in the case of the unmanured plot passed very quickly downwards to the subsoil, where in all probability it would be of little use to the crop, while the moisture from the surface layers of the manured plot passes gradually downwards, benefiting the crop on the way. This is due to the presence of humus in the surface 9 inches of the manured plot, which, acting as a sponge, retains moisture longer than the more open unmanured soil.

6. **Recognition of fertilisers.**—Obtain a small quantity of each of the fertilisers mentioned in this chapter, place each in a clear glass bottle, cork tightly, label carefully and clearly, and learn to distinguish one from the other, so far as their outward appearance will help you.

Fertilisers supplying nitrogen. Importance of nitrogen.—If plants be grown by water-culture, it will be found usually that the plant grown in the solution which lacks nitrogen makes the weakest growth. In fact, a crop of a kind may be obtained from soil with a deficiency of phosphoric acid or of potash, but without nitrogen there is very little growth. This lack of growth is specially marked in shortage of leaf, which points to the conclusion that nitrogen must have an important part to play in the building up of the foliage of the plant.

In addition, a supply of nitrogen from the atmosphere cannot be taken in by the leaves, as the atmospheric conditions are the same in the case of the plant growing in a solution containing nitrogen and one which receives no nitrogen in the solution supplied. Thus, we may state that generally speaking plants obtain their nitrogen from the soil, and not from the air, despite the fact that stem and leaves are living in atmospheric nitrogen. This almost inexhaustible source is of no use to them.

Different conditions in the case of the Pea Family.—At the Gordon Schools, during an abnormally cold snap experienced in the early summer of 1912, vegetable growth was almost at a standstill. Only cabbages, which were being supplied regularly with nitrogenous liquid manure, and peas, beans, lupins, and lucern, seemed to be making any progress. This was explainable in the case of the cabbages, but while most other garden crops put on no growth, and the corn was turning yellow for lack of nitrogen, these plants already mentioned, all members of the pea family, were growing steadily; in fact, the bloom of lupins was exceptionally fine.

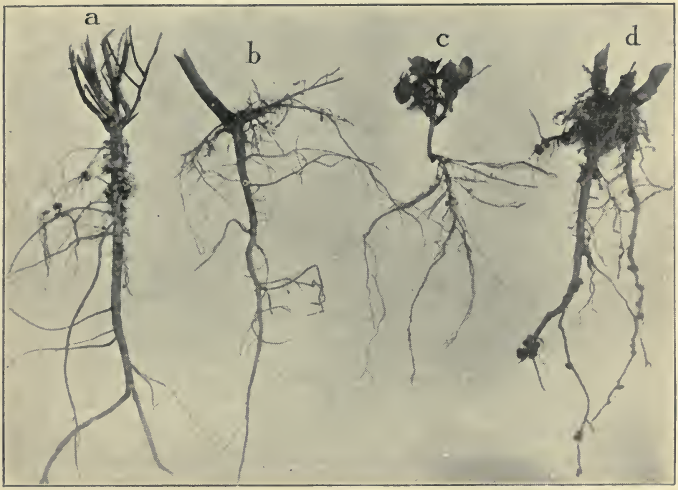


Photo Mr. H James

FIG. 67.—Nodules on the roots of *a.* lucern; *b.* broom; *c.* pea; *d.* lupin.

Nitrogen-fixing bacteria.—Obviously either these plants needed but a small supply of nitrogen or they had a means of obtaining it denied to the other crops. The first supposition was impossible because of the amount of leafage possessed by them —by lupins in particular—so that the conclusion was arrived at that they obtained nitrogen from some source other than that formed by bacterial action upon the humus of the soil. When their roots were examined they were found to possess in each case nodule-like growths, and when these were cut open and a little of the content in each case viewed under the high power of a microscope, very minute living bodies were seen to exist in the tissue of each nodule. Fig. 67 shows the nodules as found on several of these leguminosae, while Fig. 68 is a representation of the minute living organisms found in the nodules on the roots of the lupin.

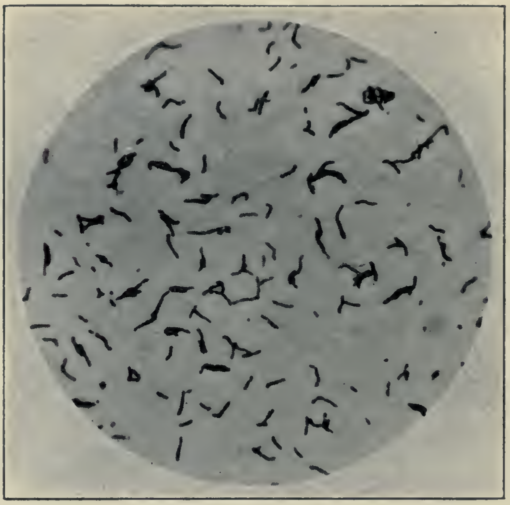


Fig. 68.—Photomicrograph of bacteria found in a nodule from the root of a lupin plant. (× 1,000.)

These organisms are bacteria capable of supplying nitrogen to the plant upon which they live. In their process of development they appropriate for their own use certain of the organic compounds which the plant has manufactured for its own food. In the combustion of these the oxygen of the atmosphere is used up, while the nitrogen is retained or "fixed," and is thus supplied to the "host" plant through the cells of the nodules. Thence it passes by absorption to the roots, and so on, until it becomes part of the compounds which the leaf manufactures from raw material, and are used as food by the plant.

In this discussion we have not only been impressed with the importance of an adequate supply of available nitrogen existing in the soil for the plant, but we have seen that the only provision made by nature for the continuance of this supply is that of bacterial action. Should this fail by one means or another, the crop must suffer. This fact very naturally caused soil-workers to seek some other means by which this element might be applied to the soil, and the result is that to-day we have several artificial fertilisers containing nitrogen in a more or less soluble condition, the more important of which we shall discuss now shortly.

Nitrogenous fertilisers—nitrate of soda.—The two chief nitrogen-containing fertilisers in use at present are nitrate of soda and sulphate of ammonia, of which the former seems to be somewhat more popular than the latter. Practically the whole European and American supplies of nitrate of soda are obtained from Chile, where it exists as a deposit on an arid elevated table land in the province of Tarapaca, a short distance inland from the sea.

The substance is very readily soluble in water, and its persistence in this region is due to the climate; rain falls but rarely, in fact but once in a few years, and then so slightly that it is very soon evaporated. The deposit lies a few feet under the surface, and when dug out is by no means pure. It is procured from the ground by blasting, and the resulting material, "caliche," as it is called, is put through several processes of purification ere it emerges as nitrate of soda. Immediately the nitrate is applied to the ground and dissolved in soil-water, it is ready to be absorbed by the plant. Naturally in such a case it should not be applied save when the roots of the crops are already *in situ* and prepared to absorb it, for it will pass away from the soil in drainage water if it is left unappropriated for some time.

Application of nitrate of soda.—One word of warning, however, is necessary in connection with the use of this manure. It is a concentrated salt; and when dissolved in soil-moisture causes the formation of a very strong solution. In discussing the passage of soil-moisture into the root-hairs, it was remarked that the cell of the root-hair contained a sap-solution of a certain strength, while the soil-moisture solution was much weaker. This results in a want of equilibrium in the solutions outside and inside the wall of the root-hair; passage of moisture at once begins from the soil into the cell, and this tends to continue until the percentage of dissolved matter is equal outside and inside the wall.

But if the more concentrated solution be outside the cell wall, as it will be in all probability if a few particles of nitrate of soda dissolve in the soil-moisture very close to the root-hair, at once, in the attempt to restore equilibrium, sap will pass from the root-hair towards the soil-moisture in order to dilute the latter, and reduce its strength to that of the cell-sap. The stronger the soil-solution the more rapidly will this occur, until the result is that so much water can be withdrawn from the cell that it becomes limp, and in some cases dies.

Effects of nitrate of soda upon soil constituents.—Nitrate of soda is applied usually on account of the nitrogen it supplies to the growing crops, but it has another effect which is often overlooked. Not that it supplies any other food-material directly to the plant itself, but the soda part of the manure acts upon the clay part of the soil, letting loose a small amount of potash, which is thus rendered soluble in soil-water.

Thus the application of nitrate of soda causes an increase in the amount of nitrogen, and to a certain extent of potash, which the soil contains in a soluble condition. Therefore, to those crops for which nitrate of soda is used in a garden, the direct application of potash, except in the form of wood ashes, is not needed. The soda base helps to rectify any deficiency of potash which may occur; and the only other manurial substance necessary for a complete manure is phosphoric acid.

Effects of nitrate of soda upon crops.—The most obvious effect of the application of nitrate of soda to crops is more luxuriant leafage, the colour of which is a dark green; but this is found usually to be accompanied by an even more important result as regards the growth of the crop. Plants grown with nitrate of soda are almost invariably more deeply rooted than are those to which this manure has not been applied. This deep rooting has of necessity the result that maturity is delayed, as the roots are extracting food-material from the soil depths long after shallow-rooted plants of the same crop have ceased to absorb soil-moisture. The application of nitrate of soda thus usually results in a later harvest, but a much greater show of leafage.

In the case of early potatoes neither of these results is desired, so this manure is not much used. The members of the pea family, as we have found, do not depend much upon manure for their supply of nitrogen, and there remain for consideration such crops as cabbages, lettuces, taproots, turnips, etc. Now leafage in cabbage and lettuce is most important, and good crops might be grown for two years or so but not more, by manuring with nitrate of soda alone. This of course is not advisable, as it impoverishes the soil. Turnips are a crop which require nitrate of soda badly just at the early stage to pull them through the flea-beetle stage, and after this need no further application in good ground.

Root crops in every case benefit from an application of nitrate of soda, and on the Continent large quantities of this manure are used in the cultivation of sugar beet. In addition, a slight application to almost any crop or flowering plant in a cold spring is bound to have beneficial results, small quantities being given as a surface dressing at intervals of a fortnight or so.

Sulphate of ammonia.—As a supplier of nitrogen this manure is equal to nitrate of soda, and in ordinary circumstances begins to act almost as quickly. It also is freely soluble, but gives best results when there is a sufficiency of lime in the soil. In fact, in ground deficient in lime this manure tends to produce acidity of the soil, and thus to hinder the growth of crops. This, however, is the case only where lime is not present or is not supplied in the necessary quantities.

Sulphate of ammonia is produced from coal, which, as the remains of vegetation, must contain a certain amount of nitrogen. When coal is subjected to destructive distillation, the nitrogen is given off as ammonia, and in gas works this ammonia is recovered by making it combine with sulphuric acid to form sulphate of ammonia.

Effects of sulphate of ammonia.—Sulphate of ammonia must be changed into nitrate of ammonia ere the plant can make use of the nitrogen, and this fact has a deal to do with the different action of this manure compared with that of nitrate of soda. Sulphate of ammonia persists somewhat longer in the soil, and its action results largely in surface rather than deep roots. On account of its persistence it may be spread in the drills at the time of sowing or planting, while nitrate of soda is applied as a top-dressing after the plant has begun to grow.

Soot.—The products of the burning of coal contain a certain proportion of nitrogen in the form of ammonia, and soot is therefore of value as a manure. The percentage of ammonia it contains is not great enough to render this article of much commercial importance, but for the gardener soot has certain qualities which justify its use on the soil. Its manurial value is not very great, as has been said already, but in early spring, when the soil is too cold for the active formation of nitrates, certain crops, onions, cabbages, etc., benefit largely from the application of even the small amount of the readily available nitrogen which soot contains.

In addition, a fact already ascertained, namely, that soot on account of its colour helps the soil to absorb more heat during the day and reduces radiation by night, results in soot-strewn soil presenting very suitable conditions for plant growth in early spring. This period, too, is the season during which slugs play most havoc among young seedlings, and if these latter be surrounded by soot, danger of attack is minimised, as soot is evidently repugnant to such pests.

Fertilisers supplying phosphoric acid. **Sources.**—Generally speaking, there are three main sources whence these manures are obtained, viz. bones, phosphate-bearing rocks, and the phosphate contained in certain iron slags. In each case the phosphoric acid is contained in the form of phosphate of lime.

Bone manures.—As a manure the value of bones has been recognised for very many years. It is natural, of course, that all products of animal and vegetable origin should be viewed as usable as a means of returning to the soil part of what has been taken away in the form of crop; but the exact action of each was for a long time unknown. Hardly a century and a half has elapsed, indeed, since it became known that bones were manurial chiefly on account of the phosphoric acid they contain. But for all that their efficacy was evident, and the demand grew until in the first half of the nineteenth century the home supply ran short, and bones began to be imported from abroad. Even India and South America at the present day send bones to Britain, and thus help to enrich our fields and gardens.

At first, bones were merely broken into pieces and applied. Naturally their effect was not noticeable in some cases for years. Later, they were ground to a coarse powder, and this is sold to-day as bone meal. But even this meal is not fine enough to give an immediate return for outlay, though where lasting effect is desirable, as in the case of making a rose bed, coarse bone meal gives good results. A much more available source of phosphoric acid is steamed bone flour, which is a very fine whitish powder free from bone cartilage. As a supplier of phosphoric acid it may be looked upon as an extremely suitable manure, especially for light soil poor in lime.

Superphosphate.—Perhaps the phosphate-supplying manure most commonly used is superphosphate. It is made by treatment with sulphuric acid of mineral phosphates obtained from phosphate-bearing rocks found in the north of Africa, chiefly in Algeria and Tunis. Phosphates are also found in North America, but practically the whole of the supply for the British manufacture of superphosphates comes from Northern Africa. The material is dug from the deposit, ground down to a fine powder, and is then treated with sulphuric acid, which increases the availability of the phosphoric acid in the composition. It may be considered the best phosphatic manure for all soils save light sands deficient in lime and peaty ground.

Basic slag.—A large number of iron ores contain quantities of phosphates, and if permitted to remain in the iron this phosphorus gives an inferior steel. By a special process the molten iron comes in contact with lime, which at once takes up the phosphoric acid. This "slag," or impure matter obtained from the process, was found to be manurial, and was termed "basic" because of the lime base in its composition. The percentage of phosphoric acid present ranges from 12 to 20 per cent., and the whole takes the form of a very fine black powder.

As basic slag contains in itself a certain amount of lime, it is specially valuable for clay soils deficient in this substance and also for peaty ground.

Effects of phosphatic manures upon crops.—Analysis of the grain of wheat, etc., of the seeds of pea and bean, of the root of turnip and the tubers of the potato (*i.e.* the parts containing a store of laid-by manufactured food), shows that these parts of the plants contain a larger percentage of phosphoric acid than do the stems.

But field and garden experiments with manure show even more markedly that the application of phosphatic manures has a very strong influence in furthering greater developments in the above parts of these plants. Naturally the strong development of these parts restricts the prolonged growth which is the result of the application of nitrogenous manures, and assists in the production of an early harvest. Apart from this, it is well known among gardeners that a slight touch of phosphatic manures causes the growth of a much stronger plant all round, no matter what the crop be. This may be partly due to the fact that somehow or other the presence of phosphoric acid results in a marked increase in the root system of the plant.

The student should prove this for himself, growing one plant in each of two large pots, one receiving a little superphosphate and the other none. The increase of roots is especially important in the case of dry soils and shallow-rooted plants.

Effects of phosphatic manures upon the soil.—As in the case of nitrate of soda and sulphate of ammonia, the presence of lime in the soil is imperative if phosphatic manures are to benefit the crop. The lime acts upon the manure, the phosphoric acid set free by this action combines with some base already present in the soil, and the resulting compound remains wholly in the surface layers, so that there is no fear whatever that it may be washed out in the drainage and lost.

In soils deficient in lime, basic slag is the preferable manure, especially should the ground show signs of "finger-and-toe" of turnip and cabbage. This is so because the lime contained in the slag hinders the development of the spores of this disease. In fact superphosphate should in no circumstances be used upon ground in which this fungus is present.

Fertilisers supplying potash.—The habit of applying wood ashes to garden plots is quite common, but usually the end in view is to prevent the unwelcome visitations of insect life rather than to supply any of the materials of plant food. Yet the time was when wood and straw ashes were collected for this latter purpose, and occasionally one finds them used systematically with the same end in view. "Pot-ashes" have long been known as supplying potash, the third of the mineral constituents of the soil whose presence was found indispensable to plant growth (Fig. 69), and so all bonfire remains should be carefully collected and applied to the onion and carrot bed. In fact, save for potatoes, a potash fertiliser need not in these circumstances be bought for the garden.

Only about the middle of the nineteenth century were means found for providing large supplies of this substance, when near the town of Stassfurt in Germany extensive deposits of potash salts were found to exist. The purer salts, sulphate of potash and chloride (or muriate) of potash are obtained by bringing the dug-out salts into solution, and then crystallising them by evaporation, while a mixture more commonly used in farming, kainit by name, is manufactured by grinding down the original impure salt materials.

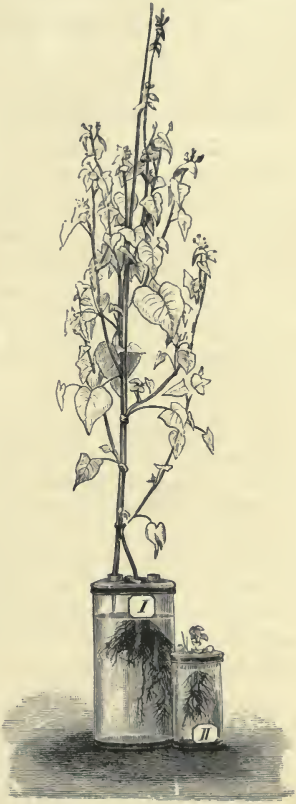


Fig. 69.—Water-culture. *I.* In nutrient solution containing potash. *II.* In nutrient solution without potash. Plants reduced to same scale.

Kainit, of course, does not contain nearly so high a percentage of potash as either of the two other compounds mentioned. For this reason sulphate of potash and muriate (or chloride) of potash are the more suitable for garden work; but in general practice it will be found that sulphate of potash is the potash fertiliser commonly used by gardeners. Kainit is useful, however, when the trenching of turfed ground is in operation, and if applied to the buried sods acts beneficially in aiding their decay and killing off insect life. It is also used by some, because on account of its bulk it is much more easily distributed than is sulphate of potash.

Effects of potash manures.—By growing crops with a sufficiency of nitrogen and phosphoric acid, and by varying the amount of potash supplied from none to more than the plant requires, it has been found that potash has to do with the building up of such substances as starch and sugar, which we have found are compounds in the composition of which carbon plays an important part. Thus such parts as are composed largely of starch or sugar, *e.g.* tubers of potatoes, roots of beet, bulbs, etc., suffer, and do not reach the size they would under natural conditions if the supply of potash be deficient.

As a rule most soils in this country, especially clay ground, have large stores of potash locked up in their composition, and in garden work, to obtain all a crop needs, save perhaps for potatoes, it is usually sufficient to supply such a fertiliser as nitrate of soda, the soda base of which acts upon the soil potash, rendering it soluble, and thus ready to be used by the plant. So that if it be the custom to give a top dressing of nitrate of soda, there is usually little need for a potash fertiliser save, as already mentioned, in the case of potatoes. Any deficiency can usually be made up by the application of wood ashes to carrots, onions, etc.

Lime.—In speaking of the lime-content of the soil it must be understood that carbonate of lime (calcium carbonate) is referred to, and when a gardener speaks of "liming the ground" he means increasing the amount of calcium carbonate which the soil contains. Carbonate of lime is practically insoluble in water, but several factors combine to reduce the lime-content of the soil. In the discussion of the action of the "special" fertilisers mentioned above it has been found in several cases that they render carbonate of lime soluble.

In the chapter on soil bacteria, it has been seen that by the decay of organic matter in the soil carbon dioxide is liberated, which, with the soil-moisture, forms a solution by which carbonate of lime is dissolved. All this results in lime being brought into a condition in which it is usable as food-material by the plant or is drained away, and the consequence is that the lime-content of the soil is reduced until it becomes deficient. Now this has more than one harmful effect. Not only is this constituent of plant food-material lacking, but at the same time the soil becomes more and more acid as the lime is used up, until at last neither can useful bacteria work, owing to the acidity, nor do certain manures have an opportunity of being made the best of. Thus a soil lacking in lime is one which does not give adequate return for the manure applied, and also bears poor crops.

7. **To find whether a soil needs liming.**—Dig a trowelful of soil from different spots of the garden, mix the lot well together, take about three handfuls of the mixture free from stones, and mix with water to the consistency of cream. Leave for a few minutes until the bubbles of air have escaped. Now pour on some hydrochloric acid, and stir with a piece of wood. Do you note any effervescence? Is it brisk or slow?

Carbonate of lime is not soluble in pure water, but when treated with a solution of hydrochloric acid it quickly comes into solution, as will be seen by dropping a small piece of limestone into the liquid. In the above test the presence of effervescence is a sign that the soil contains sufficient carbonate of lime. If no effervescence, or very little, is obvious, then the ground needs liming.

Liming garden ground.—The best form in which to apply lime to garden ground is that known as quicklime, lime shells, or stone lime. It is obtained from different forms of calcium carbonate, *e.g.* limestone, chalk, etc., by heating these substances until the carbonic acid is driven off. The resulting substance is the quicklime mentioned above. This is the form used by masons, farmers, etc. As can be seen in the working of quicklime by masons, it readily combines with water, giving off heat in the process (note the burnt-brown condition of the boots worn by most masons' labourers at their work), and falls into a very fine powder. This is called slaked lime, a condition to which the quicklime is soon brought by the moisture in air and soil. By exposure to the atmosphere this slaked lime combines with the carbonic acid of the air, and the original carbonate of lime (calcium carbonate) is reconstructed. It is this carbonate of lime which is beneficial to soils. By applying limestone, chalk, etc., crushed to a fine powder, the same result would be attained, but these are not readily obtained in powder form. Quicklime ground into powder is the handiest form for garden use.

Effects of liming.—The application of lime is followed quickly by an increase of bacterial action consequent upon the decreased acidity of the soil. These bacteria require organic compounds to maintain their existence, and, as has been already seen, they seize upon the compounds contained in the decayed organic matter present in the soil, thus reducing the humus content. Now few things are more important for a soil suitable for plant growth than a plentiful supply of humus, so that if liming be resorted to, harmful effects must be obviated by the application of organic matter in the form of farmyard manure. Indeed, it is not safe to lime ground heavily oftener than once in four years, and a moderate supply is usually found to be more beneficial than a large amount, as the natural conditions of the soil are thus not disturbed, and the oxidation of organic matter is not so rapid as suddenly to reduce the humus content beyond what the soil needs.

If farmyard manure is applied regularly every year, ground lime at the rate of 7 to 10 lb. per plot (30 feet by 9 feet) may safely be given at the same time, or better still, perhaps, in early spring before sowing.

Lessons for the garden-worker.—From this discussion, apart from information of a more or less particular and semi-technical nature, a number of important conclusions may be arrived at by the garden-worker. If a garden continues year by year to yield crops of good quality, then evidently the treatment which it is receiving in the matter of cultivation and manuring is suited to the soil, and all the garden-worker can do is to experiment here and there to find out whether by modified or additional manuring he can profitably grow a heavier crop. In his experiments he will, without doubt, cause certain pieces of ground to give lighter yield than under his former system, but while this means the loss of perhaps a few stones of potatoes for one year, it results in the gain of invaluable information for all time.

But if a piece of ground is year after year yielding well, the garden-worker knows his business, that is, if his outlay is reasonable and proportional to the return, whether artificial fertilisers are being applied or not. The good garden-worker is the individual who, by thorough tillage of his ground and the use of such farmyard manure and decaying organic matter, etc., as he can obtain cheaply at hand, harvests a good crop, and then looks around to find where, by the addition of a pinch of artificials here and a handful there, he may cause a marked increase in the yield.

Care in using fertilisers.—To apply "made-up" manure mixtures or special artificials broadcast to a garden without finding out whether such manure is needed by the soil, is neither good management, good sense, nor good business. What the garden-worker has to learn is what manures the ground needs if a certain crop is to be profitable, and this he can find out for himself only by a series of experiments. And when he has found in the experimental plot—for the whole of this chapter has a special bearing on manurial experiments —that, say, a little potash increases his crop of potatoes, he must apply the fertiliser with judgment, beginning with a small quantity and increasing the amount per plot or per year until he finds out just how much potash pays. The price of the extra manure may swallow up the increase in weight of crop, or after a certain quantity of fertiliser has been applied, additional application may give no further increase of crop. The exact point at which to stop, the garden-worker must find out for himself, and the only possible method of arriving at this knowledge is by experimenting.

As a rule, it will be found that a piece of ground ceases to respond to manuring if it receives the same treatment for a number of years in succession. As land fails to give a good return if the same crop is grown upon it year after year, and responds in a marked degree when a rotation of crops is adopted, in somewhat the same manner the same manurial treatment year after year ceases after a time to be beneficial, and a change of manure is necessary. This is especially the case where farmyard manure has been applied to the soil yearly for some considerable time. A season of cropping with suitable fertilisers usually causes a marked advance in the quality of harvest. In fact, to land which has received supplies of farmyard manure steadily for several years, lime at the rate of 7 lb. per plot, 30 ft. by 9 ft., should be applied yearly to obtain the best returns.

Continuous growth required.—In a garden, what is usually necessary is sharp, continuous growth from start to cropping, without any period of stoppage of growth, if plants are to be crisp, sweet, tender, and palatable. These qualities are especially desirable in lettuce, radish, cauliflower, beet, peas, etc. A sudden shortage of food-material, or of moisture, induces stringiness and unpleasant acidity, which destroy the eating quality of the crop, and if the crop be ruined the year is lost so far as the household supply of vegetables is concerned. Radishes may be very large, yet fit for nothing save feeding for animals; and if a student allows his crops to develop in this manner, he fails as a garden-worker. When a period of drought, or of extreme cold, comes during which food-materials are insufficient for steady plant-growth, the gardener should be at hand to suit watering and manuring to the conditions and requirements of the different crops. Thus he may pull them through a dangerous time and keep growth steady, which can be accomplished only by a judicious use of water, liquid manure, and artificial fertilisers, together, of course, with such working of the surface soil as has already been described.

The student cannot fail to notice also that much valuable manurial material is too often overlooked by the garden-worker. Weeds to form a compost, fallen leaves, decaying stems, ashes of burnt waste pieces from the woodwork room, fowl-droppings, soot, even blood, are not to be despised; and the worker who takes a keen interest in his plot will find many ways of thus enriching the soil and helping to secure a larger crop of better quality.

Consideration of results.—It will be evident to the student that all discussion of the application of artificial fertilisers centres round the manurial experiments he has already arranged for in the experimental plot, and by examination of the results obtained there he should attempt to test the conclusions arrived at above, manuring his plot according to the results he obtains.

He will in all probability find that the application of phosphates results in every case in the production of a better plant, so that this manure in one form or another is necessary for the whole of his plot. If finger-and-toe is present, he knows that the safest form in which to supply phosphoric acid is basic slag.

Cabbages, cauliflowers, and broccoli respond to the top-dressing of nitrate of soda, and with such treatment the application of potash is not absolutely necessary for this crop.

The encouraging of soft growth is not desired in the case of potatoes, so nitrogen is supplied by means of sulphate of ammonia, which, however, does not result in the liberation of the potash contained in the soil, so that a potash fertiliser also is required in this case.

Nitrogen is not being supplied to tap-rooted plants by the application of farmyard manure to the ground, therefore a nitrogenous manure, together with potash in some form, is required.

CORRELATED EXERCISES.

1. A living plant may be said to be built up of three different types of substances. Name these types, and tell whence the plant derives each.

2. How is it that most plants respond rapidly to the application of liquid manure?

3. Carefully explain why the excreta of farm animals mixed with litter act as manure to the soil, providing those food-materials which are needed by plants.

4. Lupins are grown in several continental countries where the soil is very sandy and has for years been unfit for cultivation. After a time they are ploughed in, and the soil is used as agricultural land. Explain how this change in soil conditions is brought about.

5. A plot of lucern was grown for the first time at the Gordon Schools in 1911. One half of the plot received a slight dusting of soil from ground in which lucern had previously been grown. The other half received no such application. By autumn the former half bore much the finer crop. Explain this. Autumn 1912 saw the crop on the first half even better than before, but that on the second part had improved so much that it almost equalled the other. How can you account for this?

6. Explain how it is that if farmyard manure be applied to ground just before seed is sown, the year's crop does not benefit fully from the manure.

7. Account for the lack of rain in West Chile and Peru. In what parts of the world do similar climatic conditions prevail from the same causes? Can you distinguish a belt of such land on the western seaboard of most land masses about the same latitude north and south of the equator?

8. Can you give any instances of cases where climatic conditions at the present time are fairly similar to what must have existed in the German potash district thousands of years ago? Describe the process and explain.

9. Bones of animals are exported from South America for the manufacture of manure. From which district do you expect export to take place? From what ports? What kind of country forms the hinterland of these ports?

10. Nitrate of soda of 95 per cent. purity yields 15·6 per cent. of nitrogen. How much should there be in a shilling tin containing 6 lb. of the fertiliser?

11. Two rows of strawberries were treated, one with 1s. 3d. worth of nitrate of soda, and one with special manure costing 2s. The yield in the former case was 15½ lb. and in the latter 16¾ lb., selling at 6d. per lb. Which treatment was the more profitable, and by how much?

CHAPTER XII.

FRUIT-TREES AND BUSHES.

Dormant period.—In common with most living organisms, fruit-trees and bushes enter into a period of rest, which in this case may be termed **plant-sleep.** During this time, which usually extends from late October to mid-March, the plant is by no means dead, a fact which can be learnt by cutting a twig with a knife. The exposed wood will be found not dry and lifeless, but green-coloured, and showing evidences of sap. In fact, at no time probably, or during but a short time at most, does the living tree in Britain cease to perform some of those functions which are associated with life, but during this period the performance of these is so very faint and slow as to be almost imperceptible. The plant is partaking of a period of rest, partly as a means of withstanding the rigours of winter, and is said to be **dormant.**

This condition is preceded by certain preparations on the part of the plant itself. First of all, food substances which have accumulated in the leaves are passed downwards and stored in the stem and branches. When the cold dry winds of winter blow, the plant is better without these leaves, dissipators of the moisture as they are, for through them would pass away, as vapour, precious sap which cannot be replenished on account of the coldness of the soil. So by a gradual process, a corky layer of bark grows over the spot where the leaf joins the twig, the sap channels are thus closed, and subsequent escape of moisture by this means is rendered impossible, while the leaf naturally falls away, leaving a closed scar to mark its place of connection with the twig (Fig. 75).

Buds also, which have been formed during the current season, are not exposed to the drying winds of winter, but lie snugly encased in corky hair-lined coverings. And to make loss of moisture doubly impossible, some trees even coat the buds with a resinous covering, which renders them quite waterproof.

Thus, a food supply stored in itself, all possible exits for water carefully closed, roots firmly fixed in the soil but no longer able to absorb soil-moisture—partly because of the temperature of the soil and partly because of the fact that there is no outlet for water upwards—the tree is in a fit condition to withstand the winter.

When to transplant.—If such a tree be examined, it will be found that the wood of the current year's growth is no longer plump and slightly yielding to the touch, but hard. It is now said to be ripe, and the plant is in the very best condition for removal. But the plant does not become dormant immediately the leaves have fallen. This condition is reached by a gradual process, and the period of most marked inactivity is not arrived at until from November to the end of January, so that November is the best month for transplanting.

Sometimes the garden-worker may find it necessary to wait until late February or early March; but if the matter be considered, it will be realised that March is a month during which the soil, when it is not frozen, is very often in no fit condition for working on account of its wetness. Such softness of the soil implies more or less mild weather, resulting in stirrings of life on the part of the plant. Previous to the mild weather, the tree could not be removed as the ground was hard. With the thaw, activity in the plant began, so that it is well-nigh impossible for the garden-worker to transplant in spring and be assured he is handling a plant which is quite dormant.

This does not imply that an experienced gardener may not safely transplant in spring. His case, however, is different. By long practice he has come to be able to read plant signs; from the condition of the plant he knows when he may be sure of success, and when he is almost certain to court failure, and acts accordingly. The young student must take the plant in the depth of nature's sleep if he is to be successful. This gives the plant plenty of time to become established in its new position before the mild weather of spring causes that stirring of the sap which calls upon it to renew its activity.

Soil conditions.—We have already found that the working of soil which is in a sodden condition must result in poor growth on the part of the plant set to grow in such soil. Now, in November, the ground has not yet received its largest supply of moisture, for we have found that the greatest amount of rain falls in Britain, as a rule, during the non-growing season, so that soil should be drier and more workable in November than in spring after the winter snows have melted. In addition, in November the sun's heat is still sufficient to cause a deal of evaporation from the soil, thus helping to make it less sodden, while the heat of the sun in March is not strong enough to cause much evaporation. Thus the working condition of the soil should be better in November than in late February or in March.

But one other, and perhaps the most important, consideration must not be lost sight of. Cold naturally retards growth, and if a plant be placed in soil whose temperature is low, the result is that growth is not encouraged, and the plant does not become established. Establishment does not take place without a certain degree of growth on the part of the roots, for, as has already been noted, the plant is growing, *i.e.* undergoing physiological changes, however slowly, even during a large part of its dormant period, if by this be implied the period during which it is leafless. Now if very cold soil be placed in contact with the roots, growth in these ceases, and the plant fails to become established; so that whether in November, or in spring, transplanting should never be done during frosty weather.

The warmth of the soil, therefore, is of importance in connection with transplanting; and it scarcely requires the taking of soil temperatures to arrive at the understanding that the earth must be warmer in late autumn ere the summer warmth has been quite lost, than in early spring after a period of cold and before the heat of the sun is strong enough to have very much influence upon soil temperature. For the same reason, transplanting in winter, even during a period free from frost, is to be condemned.

1. **Preparation of the ground.**—If planting is to be done in November, the ground must be well dug over in October. Trench the soil as already advised, laying in farmyard manure in the same manner as

in the plots for vegetables. If trees are to be grown on wires, the posts should now be put in, at least 2 feet deep. Larch tree-trunks, unbarked, suit the purpose, and they should be ordered 9 feet long. The end post may be supported as advised in the case of corner posts for the fence around the garden (Fig. 20). Do not run the wires into position until the trees are forward, when you can suit the wire-space to the distance between the pairs of branches.

Soil preparation.—It is absolutely necessary to prepare the ground in October if planting is to be done in the following month. By this method the soil sinks well down of its own accord, and the fine particles are washed into air-spaces by the action of rain. If trees be planted in soil which has not settled, the sinking soil will take the tree along with it, and it will appear to be planted too deeply. Good ordinary garden soil, capable of growing a fair crop of vegetables, is suited for fruit; and indeed the digging-in of manure in such a case may be omitted. Nothing is gained, but much lost, by rank growth in fruit trees, and much farmyard manure is apt to cause the tree to run largely to leaf and branches—just what the fruit-grower does not desire. If trees are to be grown on wires, the line of posts should run as nearly north and south as possible. Otherwise one tree overshadows another, and harvest is delayed.

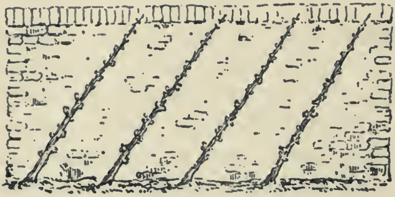


FIG. 70.—Cordons obliquely trained.

2. Types of trees and bushes.—Examine the ground set aside for fruit-trees and bushes. Is it bordered on the north by a wall of any kind? If so, reserve this for fruit-trees. Is the south or east shut in by a wall? Black currants and raspberries do well in such a situation. Part of the wall facing south should have single oblique cordons grown upon it (Fig. 70), the end parts of this space, which would otherwise be bare, being filled up by trees grown as shown in Fig. 71. Here, too, should be found room for a double cordon (Fig. 72), and for a tree horizontally trained as in Fig. 80. Single cordons horizontally trained (Fig. 73) will find a place upon wire stretched along about a foot from any path in the fruit-plot, preferably one running north and south.

The south wall of the garden shed will usually be available for one tree trained in a fan form. In any out-of-the-way corner of the garden, a standard should be grown (Fig. 84), but it must have plenty of room to develop and must not overshadow any growing crop. Sun-lit corners of the fruit-plot should be retained for trees grown in the dwarf-bush and pyramid forms (Fig. 74).

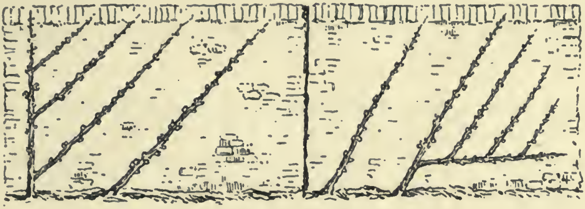


Fig. 71.—The filling up of end spaces on walls.

If space be available, gooseberries also should be trained in special forms as are fruit-trees. The cup-shaped bush, pyramid, single and double cordon, and fan-shaped forms should all be attempted.

If at all possible, a clear space should be kept in the fruit-plot where at least one new "maiden" tree can be planted each year, the same variety of stock and scion (p. 180) being used for each successive tree. Thus a row of trees of the same variety each one year older than its neighbour will be had.

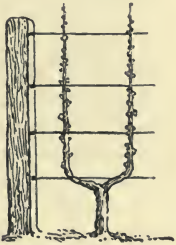


Fig. 72.—Double cordon.

Laying-off the fruit-plot.—It is but too common to find that this part of the school garden is laid off by an experienced gardener who, while an expert upon the varieties of trees and bushes which do best in the neighbourhood, has no idea whatsoever of the possibilities which this plot presents from an educational point of view. It cannot be emphasised too strongly that the purpose of the fruit-plot in the school garden is first of all educational; and, secondly, but of considerable less importance, horticultural.

A fruit-plot which contains just those trees which bear good crops in the special part of the country in which the garden is situated, most of them of one type, and all already partially trained by the nurseryman, has no real place in the school garden. A fruit-plot it certainly is; from the point of view of the expert, perhaps perfect; but its deficiencies and its wofully useless excellence only too soon impress themselves upon the garden-worker, and sooner or later an instructor of sufficient insight and personality will come along who will root-up the whole set of trees, and plant afresh.

3. Space between trees and bushes.—Single oblique cordons do quite well at 18 inches apart, and double cordons at 2 feet. Single cordons trained horizontally on wires alongside a garden path require but 5 feet between the trees, while trees trained as in Fig. 80 require 9 feet between the stems, if full development is to be had.

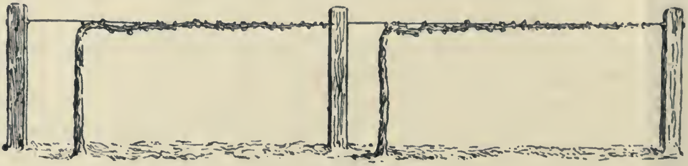


FIG. 73.—Cordons horizontally trained.

Should it be necessary to grow all the trained trees, save those of pyramid form, on rows of wires stretched across the garden ground, while a few trees of the type shown in Fig. 80 should certainly be grown, the whole ground should not be taken up with them, nor should they stand exactly behind another in the rows. If two of the type, Fig. 80, be grown, let them be planted as remote from each other as possible, for this is one of the strongest-growing forms. Allowance, of course, must be made for subsequent growth, but that does not necessarily imply that two 6-feet or so spaces of soil on either side of the tree must be left tenantless.

Until such time as the branches of the tree increase in length, here is available ground, and the desired support for a double cordon apple-tree, for a palm-shaped gooseberry plant, or for the yearly addition of a "maiden." Rather fill up vacant spaces than leave them bare. It is unnatural for soil to bear no crop, as nature will soon give evidence by a copious growth of weeds.

4. Varieties of stocks.—Examine a fruit-tree from the nursery. Can you find a point just above the ground line where it is evident that growth is unnatural? Is there any evidence of part having been cut away here?

Fruit stocks.—Practically all cultivated apples and pears are grown on stocks which are not their own. As in the case of roses, a stock different from the fruit-bearing part has been chosen. Roses are budded on briars which are of more robust growth than the original rose-bush, thus causing stronger growth and longer duration of bloom in the rose. Apples and pears, on the other hand, bear but poorly when they develop much wood and leafage, so that they are budded on stocks of the very opposite character to the briar, *i.e.* dwarf-growing.

From this the student will realise that if full educational advantage is to be taken of the fruit-plot, he must include in his selection of trees at least two plants of the same variety of apple, one grown on the *crab* and one on the *paradise* stock; and in the case of pears, one on the *ordinary pear* and one on the *quince*; so that he may watch the method of growth of each, and may arrive at a knowledge of the type of stock to choose for any given situation.

Varieties of fruit trees and bushes.—So many new varieties appear each season that it is difficult to state definitely which are the best. Besides, it has been found that, as in the case of vegetables, certain varieties do better in certain districts than do others. Thus an error of judgment at the outset, when the trees and bushes are being chosen, is a serious matter, for it may mean the loss of three or four years, as some trees take that time before they become fully established and show their bearing powers. The beginner is advised to interview as many good growers of fruit in his district as possible; get them (gardeners are as a rule kindly souls) to draw up a list of the best varieties to suit local conditions of each kind of fruit intended to be grown in the school garden, arranging them in order of merit, and

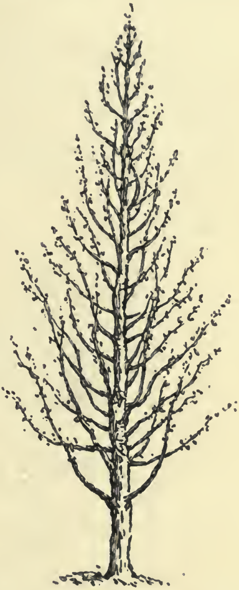


FIG. 74.—Pyramid form of tree.

when a number of opinions have been obtained, select the most popular.

However, in case such assistance is not to be had readily, the following list of what are considered good varieties is given. Having made his selection, the garden-worker in sending his order to his nurseryman should add a postscript to the effect that the latter might suggest suitable varieties, should the list fail to include the best for the district. Or better still, when visiting the nursery in July to choose roses for the garden, the student should choose fruit-trees and bushes at the same time, care being taken that the plants chosen are quite free from disease, have made stocky rather than luxuriant growth, and have not been grown close together in the nursery.

Apples.

Cooking.

Keswick codlin	August and September.
Warner's King	November to January.
Blenheim orange	November to February.
Lane's Prince Albert	November to March.
Ecklinville seedling	October to December.
Northern greening	Latest of all.

Dessert.

King of Pippins	September to January.
Cox's orange	October to January.
Allington pippin	November to January.
Ribston pippin	November to March.
Bramley's seedling	November to April.
Sturmer pippin	Latest.

Pears.

Jargonelle	August and September.
Louise Bonne	September and October.
Pitmaston Duchesse	October and November.
Winter Nelis	Latest.

Plums.

Cooking.

Orleans	August.
Pond's seedling	September.
Victoria	September.

Table.

Greengage,	September.
Kirke's,	September.
Coe's Golden Drop,	October.

Red currants.

Comet. | Raby Castle.
Fay's Prolific.

White currants.

White Dutch. | White Versaillaise.

Black currants.

(Obtain a guarantee that the nursery is free from black currant mite, p. 280.)

Naples. | Boskoop Giant.
Carter's Prolific.

Gooseberries.

(Obtain a guarantee that all the plants you receive are free from American gooseberry mildew, p. 284.)

Red.	*White.*
Whinham's Industry.	Venus.
Crown Bob.	Whitesmith.
Victoria.	Lancashire Lass.
Yellow.	*Green.*
Golden Lion.	Keepsake.
Leader.	Pitmaston Gage.
Phoenix.	General.

Raspberries.

Baumforth's seedling. | Fillbasket.
Superlative.

Strawberries.

Royal Sovereign,	Early.
The Laxton,	Early.
Sir Joseph Paxton,	Mid season.
Duke of Edinburgh,	Mid season.
Myatt's seedling improved,	Late.
Givon's late prolific,	Late.

Distances at which to plant.

Gooseberries,	5 feet apart each way.
Currants,	5 ,, ,,
Raspberries,	4 feet apart in the row.
Strawberries,	1 foot to 18 inches apart in rows which are 2 feet apart.

5. Labelling.—Carefully label each tree and bush immediately it is placed in position. The paper labels which have been affixed by the nurseryman are useless, as they decay in quite a short time ; so wooden labels must be made. Write the names with a soft "garden" pencil and then dip the labels into a bath of thin white paint. The writing will show through the paint and will not be washed off by rain. Tie the labels loosely to a branch, using wire in preference to string.

In addition, draw out a plan of the fruit-plot, placing the names of the plants in the correct positions. Hang this up in the potting shed, where a similarly named plan of the rose-plot should also be kept.

6. Preparations for planting.—If the weather be fine when the trees are forwarded, plant at once ; if frosty, store where they are safe from frost for a few days till the weather changes.

Carefully measure off the position of each plant according to the plan you have drawn, and mark the exact spot with a stout peg.

Now examine the plants, which until now have been unpacked. If the roots seem dry, immerse them, and as much as possible of the stem, in a tub of water for a couple of hours. When they are taken out the wood will have become quite plump. Leave each in the water until it is to be planted.

Dig out a hole where a peg is placed, making it large enough to take in all the roots of the tree or bush when they are spread out naturally all round the plant (4 feet diameter of hole for a tree and 3 feet for a bush usually suit). The plant must be sunk in the soil to the mark on the trunk which shows how deeply it had been placed in the nursery-ground, but the hole itself must be dug out much deeper than this. Tread the centre of the hole well, shovel in more earth to the centre, tread, and add more soil, which is in turn made as compact as possible by treading. This goes on until there is a round mound of firmed soil in the centre of the hole, and earth must be added to it and made compact until when the plant is placed on the top of this mound, the roots being well spread over the sides, the mark on the trunk is just at the ground line.

Examine the tree. Does it show any central coarse root growing straight down? If so, cut this away about 6 inches from the trunk, using a small saw should a pruning knife be too weak. Now examine the remaining roots. Are any broken? If so they must be cut away with a clean cut. Are there any straggly roots on the plant, showing long, weak growth with wounds or unnatural growths? These must be cut just above the wound or growth nearest to the stem.

7. How to cut back roots.—The method of cutting is important. Only a sharp knife must be used. All cuts made right through a stem, branch, or root, are made in a slightly slanting direction, right across the portion of the plant being cut. In cutting a stem, or upward-growing branch, the direction of the cut should as far as possible be parallel to a line drawn at an angle of 45° from the base of the stem upwards, and should pass outwards from the plant. A root should be cut in exactly the same direction, always beginning the cut on the under side of the root, *i.e.* the side furthest away from the surface of the soil. Cut away only very thick gross roots, slightly trim thinner ones which have been torn or broken, and cut back diseased roots.

8. Planting.—Place the plant vertically in the hole, the base of the stem resting on the mound of packed soil and the roots carefully spread out over the side of the mound. Shovel in some earth, slightly raise the plant and lower it sharply into its original position, pack home the earth with the foot, and place more soil in position. This goes on until the hole is quite filled up to the surface, save that the final 6 inches or so of soil are not trodden down but firmed with the back of a fork, and the surface slightly raked. If rightly planted, no tree save those trained to be grown against a wall or on wire should need any support whatsoever.

Moisture-requirements of the plant.—The great mistake commonly made in planting trees just received from a nursery is that of allowing the roots to become dry before planting is done. Transpiration in a tree removed from the soil is still going on slowly by means of the buds and the young bark, so that if the roots once become dry, so much moisture may be lost that the plant becomes quite limp and sometimes fails to recover. Should it be inconvenient to plant just when the trees and bushes are received, they ought to be "heeled-in" temporarily, that is, should be set as deeply as possible in the soil in a shaded spot. If the earth is well packed around the roots, the plants receive sufficient moisture to keep them plump until they are planted.

Preparation of the plant.—Naturally in the removal of a tree or bush from its nursery quarters many rootlets are broken, some roots are torn, and others badly bruised. A broken root-end does not heal over so easily as does one which is cut clean across, nor does it send off rootlets so readily. Consequently all broken roots should have a piece cut off with a sharp knife so as to leave a smooth surface at the end.

A coarse central root striking straight downwards is certain to result in gross leaf-and-branch production, as it sends out rootlets into the subsoil which supply the plant with moisture long after it is desirable that active growth should have ceased. The result of this is that the strength of the plant is thrown into branch-production which continues until late in the year. Thorough ripening of the wood in autumn is thus prevented, and the likelihood of winter-killing greatly increased.

Another type of root, however, is almost as dangerous, that is, long straggling growths with "elbows," thickening of the root, or disease spots. The first two indicate a tendency on the part of the plant to become rank, the latter must not be tolerated on any account as the disease may spread, so all such roots should be cut back to a point where the growth is clean and straight. What is desired for fruit production is the growth of many fibrous roots which do not cause rank growth of branches, and a fruit-tree should enter the soil with its roots cut in such a manner as to encourage such growth.

Preparing a place for the plant.—It is hardly necessary to repeat that if roots are crushed close together they compete for moisture and food-material, and thus soon exhaust the resources of the soil around them. Therefore the hole is made large enough to accommodate the whole rootage of the plant when spread out. The firming of the central mound as directed is connected very closely with what has been said already with regard to coarse strong roots which grow straight downwards into the subsoil.

Such growth, of course, is not to be permitted in fruit-trees, and the monks in the old monastery times used to place a flagstone directly under each tree planted. This effectively prevented any straight downward growth, in fact, caused the roots to spread outwards on all sides at the level of the flag. This practice has been departed from nowadays, largely as a result of the introduction of the paradise stock, which is less gross in growth than the crab.

Planting.—To keep the plant firmly in the soil during the winds of winter, to ensure that each rootlet is in close contact with soil particles, thus receiving every facility for the absorption of moisture, and to encourage stocky, hardy growth, the soil should be packed as tightly as possible around the roots. Each crevice must be filled with soil, and slight raising and lowering of the plant helps to shake the particles into each air-space. Unless this be done and the soil packed as firmly as possible around the roots, the best type of growth cannot be looked for. This firming of the soil, however, should not be continued right up to the surface, or the winter rains, as they fall, will fail to find entry into the compacted soil and will drain away over the surface.

Protection.—Should the winter locally be usually very severe, soil should be piled up round the base of the stem. This prevents any injury from ground frost. Some growers believe in the application of a manure mulch in late autumn. This certainly acts as a protection, supplies food-material to the roots, and encourages surface rooting—just what is wanted. But, on the other hand, a manure mulch forms an excellent nesting-place for mice and voles, encourages too early growth in the flowering buds owing to the abundance of readily available food-materials, and is apt to result in such shallow rooting—as so much food-material lies in the surface layers—that the plant may suffer from drought as a result.

Pruning after planting.—This is a point concerning which opinions differ, but it has been considered the better policy to advise here that no tree should be pruned, in the true sense of the word, that is, just after planting. The advice is given on the following grounds. Much rootage has been removed from the plant, therefore for some little time the amount of moisture absorbed by the roots cannot be equal to that which the plant had ordinarily received before it was removed from the nursery.

During its dormant period the plant absorbs very little moisture indeed, but when all the fine rootlets and minute root-hairs have been lost, as they generally are in transplanting, this supply is decreased very considerably. Therefore, though in late autumn and early winter the tree requires but a very small amount of moisture, yet by transplanting even this minute quantity is lessened greatly.

Now if the plant be pruned hard back, many open cuts are thus formed upon the tree, cuts which, being exposed to the weather, give off moisture by evaporation at a rate far in excess of that at which soil-moisture can enter the plant. The result will be that the tree is under adverse conditions with regard to moisture. If no pruning be done, what moisture is lost passes away by transpiration through young bark and buds, a quantity very much smaller than that lost by oozing from open wounds.

9. **Examination of a branch in autumn.**—Obtain a branch of horse-chestnut as similar as possible in form to that shown in Fig. 75. Do not select one which consists mainly of young wood, but attempt to have the growth of several years upon the branch you choose. Examine it in detail as advised below for Fig. 75.

Examine one of the terminal buds (1912); note the leaf scales. In 1913, when this bud grows into a shoot, these scales will drop off as their function has ceased. Will any marks be left on the bark to indicate the position of these scales? Can you find a series of such marks on the branch you have chosen? From this, can you find out the age of the branch?

Annual growth.—Reference to Fig. 75 will show that by the autumn of 1907 two buds had formed on the end of the branch *A*. In the spring of 1908 each of these grew out into a shoot, terminating in autumn 1908 in a bud, shoot *B* growing somewhat longer than shoot *C*. These buds in the spring of 1909 grew out into shoots, two buds developing upon *B* and but one on *C*. In this year *C* made the longer growth. In spring 1910, all three buds grew out into shoots, *B* and *C* making much longer growth than *E*, and all three shoots terminated in a bud in autumn 1910. In the spring of 1911 all three put on growth, *B* and *E* terminating in one bud each, and *C* in two buds in autumn. The spring of 1912 saw each of these buds developing, the shoots *B*, *E*, and *C* each terminating in one bud, while *D* grew out a short distance and formed a bud, the branch thus possessing four terminal buds to continue growth in the spring of 1913. This was the condition of the branch at the time the photograph was taken.

10. Buds in the axils of leaves.—Note the "horse-shoe" marks indicating the position where leaves grew, also the number of "nails," *i.e.* scars which mark the position of the vessels by which each leaf was connected to the stem. Can you find such marks on the stem at the base of the side branches *B*, *C*, *D*, and *E*? Do you note any signs of attempted growth just above where a leaf grew at other points along the stem? What do you call these growths?

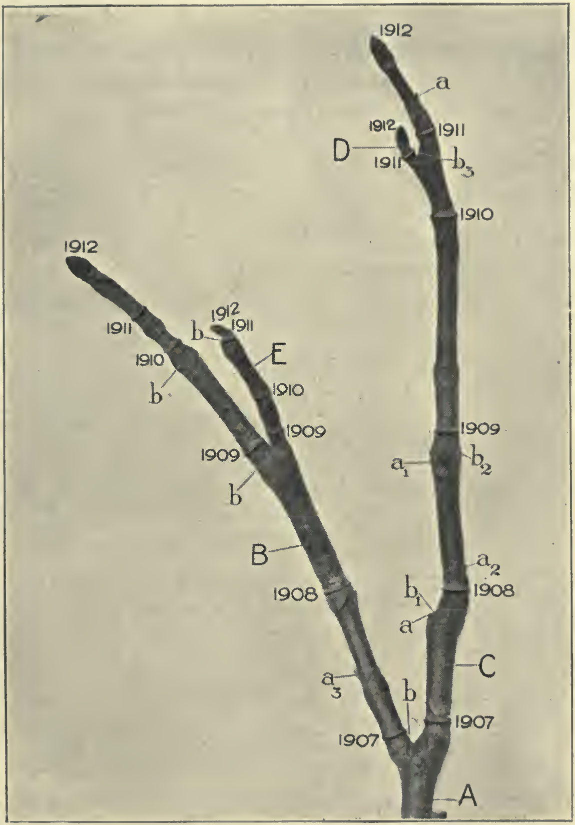


Photo Mr. H. James

FIG. 75.—A horse-chestnut branch in autumn.

Active and dormant buds.—Buds arise in the **axil** of a leaf, and these buds may grow out into branches, as in the cases *B*, *C*, *D*, and *E*; or may remain dormant as have all those marked *a* in Fig. 75. Altogether this branch has developed about twenty-eight buds, but only six of these put on growth. The others, however, are not dead. They are merely dormant, and should conditions be altered in certain ways, they will spring into growth. This point is extremely important in connection with the subject of pruning, and the student should examine branches from as many trees as possible, so that he may be able to recognise these dormant buds at a glance.

11. **Age of dormant buds.**—Calculate the ages of buds a_1, a_2 and a_3. Also the ages of *E* and *D*. Is the length of wood developed any indication of the age of a bud or shoot?

Strong and weak growth.—Already we have found that a shoot may put on long or short growth in one season, one shoot often developing at a greater rate than another: cf. the growth of *B* and of *C* in 1908. This may be due to several causes, but in the case of *D* and *E* it will be noticed that these weak shoots grew less in any one season than did either of the stronger shoots *B* and *C*. In the growth of trees this will be found to be true in almost every case, and the natural conclusion is that the stronger a shoot is to begin with, the greater amount of the available food-materials it will appropriate, and therefore the stronger it will grow. In the case of the weak shoot, conditions are reversed. Indeed, it is common to find that a shoot which is weak to begin with is at a decided disadvantage with regard to growth so long as the strong shoot remains upon the tree.

12. **Fruit-scars.**—Examine Fig. 75, or the branch you have chosen, for broad scars (*b* in Fig. 75). These scars mark the positions where fruit was borne. Note the length of wood developed during the year in which the shoot bore fruit. Does the growth of the shoot continue straight onwards from this point? Why not?

Long and short growth.—If *C* be examined carefully it will be found that during 1908 short growth was made, and fruit was borne at b_1. In 1909 again, comparatively short length of wood was made, and fruit was borne at b_2. The growth of 1910 was long and no fruit developed, but that of 1911 was short and fruit-bearing (b_3).

These conditions will not be found in every case, but instances of the above are sufficiently frequent to enable us to form a rule. "Long growth of wood in any season is usually accompanied by no fruit on the shoot. Short growth of wood in a shoot is usually accompanied by fruit-bearing."

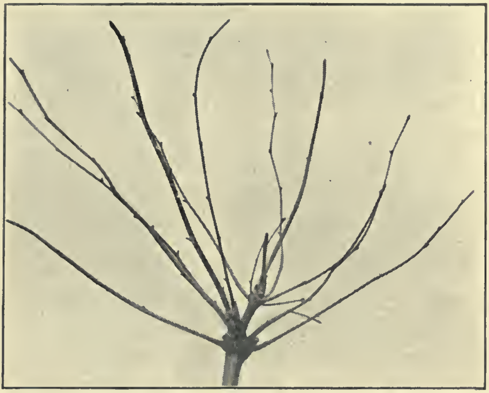


FIG. 76.—Where hard pruning was bad pruning. Note much growth of weak shoots.

Thus we have found that two causes may result in arrested wood-development. In the first place, a strong main shoot may appropriate the larger amount of the food-materials at the disposal of the branch, and put on growth at the expense of weaker shoots. Indeed, to such an extent may this proceed, that but three or four of the buds which grow upon a branch usually develop into side branches. Should the development of most of the buds take place, the result would be a mass of weak shoots (Fig. 76), as each would receive but a small quantity of food-material, the whole of which in ordinary circumstances is directed into one shoot. Thus we find that in the suppression of weak growth by the development of a strong shoot at the expense of the weaker, the plant has begun to prune itself: through the competition for food-materials, light, etc., which takes place between the shoots, the weaker go to the wall and the stronger develop growth. This naturally results in a stronger tree.

In the second place, this strong twig varies the length of wood it develops each season. It receives, let us say, a certain quantity of food-materials. If the whole of this supply be directed towards increase in length, the growth of wood must be greater than when a certain amount of the food-materials is used up in the development of fruit.

In each case, too, fruit-bearing resulted in a change of direction of growth (Fig. 75). If the terminal bud develops into flower and fruit, the usual position of the bud which would continue growth in the following year is taken up in autumn by fruit. Thus further growth from this point is impossible, and growth in the following spring must proceed from some bud situated below the point where the fruit is borne. This is very evident at the points *b* in Fig. 75. The result is that growth is not straight but crooked in a fruit-bearing branch.

13. **Examination of the branch of an apple tree.**—Obtain a two-year-old spray from an apple tree similar to *A*, Fig. 77. Note where the present year's growth commenced. What differences do you notice between the present and the previous year's growth in the type of bark, the arrangement of the leaves, the development of the buds?

Fruit-buds and leaf-buds on an apple branch.—In *A*, Fig. 77, the growth of the branch evidently changes at 1911, *i.e.* the point where the growth of 1912 began. Above this point the leaves grow singly, below this point they grow in groups, three in each case in the figure. In the axil of each leaf on the portion 1911-1912 is situated a bud, but no such single leaves with buds in their axils are evident on the growth below 1911. In the previous year the portion below the point 1911 was similar to what the piece 1911-1912 is at present, *i.e.* single leaves grew upon it with buds in their axils. The 1911 growth was pruned back to the point 1911 in the winter of that year, and upon the portion shown three buds were left, *a*, *b*, and *c*. In the year 1912, *a* and *c* bore leaves, and on strength derived from the food manufactured in these leaves the buds put on growth. In the case of *b*, however, no leaves were developed; as a result no food was manufactured, and consequently no growth was made by the bud.

So that *a* and *c* are no longer buds. They are branches of the same age as the portion 1911-1912, but their growth of wood is extremely short compared with that of the terminal shoot 1911-1912.

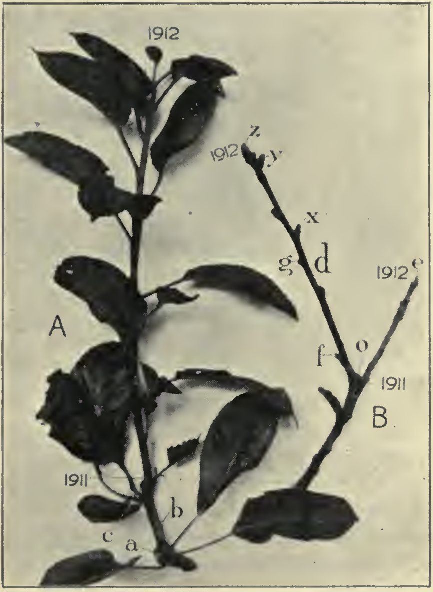


Photo. Mr H James

FIG. 77.—Sprays of apple tree.
A. A spray in summer. *B.* A spray in autumn.

Now we have found already that arrested wood-development is usually accompanied by fruit-bearing, so that in all probability both of these short branches have on their ends buds which would have developed into flower and fruit in 1913 had the branch been left on the tree. In fact, such short side or lateral branches are known as **fruit-spurs**, and one of the aims of pruning is the development of as many as possible of these upon a fruit tree.

Sometimes, however, such fruit-buds are found on the tips of branches of some length (*B*, Fig. 77). On this branch it is evident the buds are not all of the same shape. It will be noticed that *e*, *f*, and *g* are more elongated and more pointed than *x*, *y*, *z*, and here we find well shown the difference between the appearance of **fruit-buds** and **leaf-buds.** The thick-set, round-shaped, blunt-pointed buds, *x*, *y*, and *z*, will grow out into flowers and leaves in the following year, while *e*, *f*, and *g* will develop leaves only. The difference in appearance of these two types of buds is well shown in Fig. 78.

14. Gooseberry and black- and red-currant branches.—Obtain a gooseberry spray in autumn similar to that shown in Fig. 78. Note present and previous year's growth. What kind of buds do you find on the former? Are the growths on the latter similar? May these be compared to the fruit-spurs on an apple tree? Where exactly are these spurs situated?

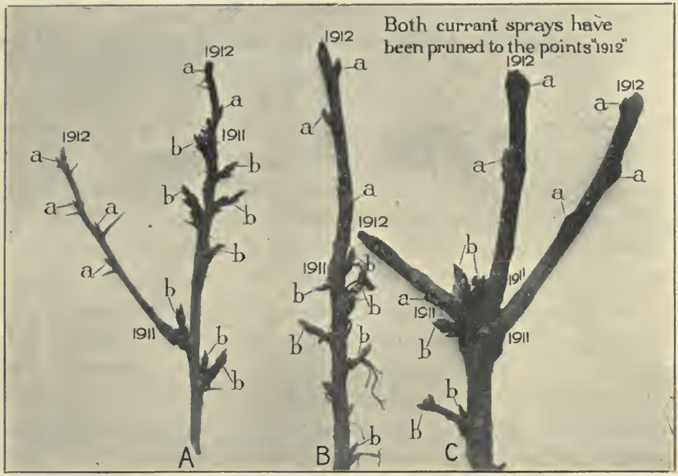
Examine a black-currant spray in a similar manner. Note the differences between growths on the present and previous year's wood. Can you find evidence of fruit-spurs? Where are they placed?

Note the persistence of the fruit-stalks of the present year in the case of black currants, although the photograph was taken in November. Note their point of junction with the spur. This marks the length of the spur at the beginning of the present year. Find also the slight change of direction of growth at this point, indicating that growth was continued from a bud situated slightly behind the position of the bud which bore fruit.

Examine a red-currant branch in the same manner. Note the position of the fruit-bearing parts.

Fruit-buds and leaf-buds on fruit bushes.—Fig. 78 shows very markedly the fact that fruit-buds are not borne by any of these bushes on the growth of the present year. In the case of gooseberries, the spurs appear in clusters on the previous year's growth; and, were a longer piece examined, it would be found that practically all wood save that of the present year, and wood which is very old, bears spurs or fruit-buds. Red-currants will be found to be almost similar.

In the photograph the fruit-spurs of the black-currant are seen plainly on the wood of the previous year's growth, while if a longer piece were examined, it would be found that no spurs are borne on old wood.



Both currant sprays have been pruned to the points "1912"

Photo Mr H James

FIG. 78.—Fruit-bush branches in autumn.
A. Gooseberry. *B.* Black-currant. *C.* Red-currant.
a. Leaf-buds. *b.* Fruit-buds or spurs.

Lessons for the garden-worker.—Increase in length proceeds in spring from buds which have been formed during growth of the previous year.

This growth tends to take place from the outermost, topmost, or terminal buds; side or lateral buds are apt to develop in a less degree or to remain dormant, Fig. 75.

Therefore, so long as these terminal buds remain on the branches, there is small likelihood of the development of the dormant lateral buds. If the terminal buds are usually leaf-buds, the result must be a long branch which bears fruit at its tip at intervals, while along its length are situated many dormant buds, each of which might develop into a fruit-bearing side shoot could it but receive sufficient food-material and sunlight.

If the shoot upon which the terminal bud is situated be strong, the subsequent development of the branch will be strong. If the shoot is weak, the continued growth will also be weak so long as any strong shoots compete for food-materials with the weak shoot.

Weak growth and short growth are by no means synonymous. Weak growth may be long and thin but still be weak, while short growth is perhaps better described as partially arrested or checked growth.

Short growth is usually accompanied by fruit-bearing. Long growth seldom terminates in fruit.

It is possible in late autumn to distinguish between those buds which will make growth of wood in the following year and those which will develop flowers and leaves.

Evidently then the above observations centre round two aspects of plant growth. In the first place, they direct attention to the general method of growth of the tree, *i.e.* that a tree tends to put on increase of length by growth from terminal buds on its branches. The grower, however, desires the development of side or lateral growth as well. Secondly, attention is drawn to the fact that two distinct types of buds are developed, leaf-buds and flower-buds ; and it has been made obvious that it is to the interest of the garden-worker to encourage the growth of fruit-bearing buds and restrict the tendency of the tree to run to wood.

A word of warning.—The above observations imply that the garden-worker is about to lay hands and knife upon the tree, in order to compel it to develop according to his requirements. But we have already found that a plant is a living organism, performing in accordance with natural laws certain functions, each of which is intimately related to the other. So persistent is the operation of these functions that, as we have already seen, the plant makes an attempt to fulfil its purpose in nature no matter how unfavourable its circumstances may be physically and manurially ; and, as a rule, it succeeds. Now when the garden-worker applies a knife to a tree to prune it, it will be well if at the outset he realises that he is interfering with nature, and is undertaking an operation by which the machinery of the plant is thrown temporarily out of order. Let him at the same time remember that such disarrangement is merely temporary.

In accordance with natural laws, the plant will struggle to regain its former condition, often in the process introducing variations unexpected and most undesired by the pruner.

Balance between rootage and leafage.—Consequently certain facts must be recalled. First of all, let it be remembered that the plant's present method of growth is natural. If it sets itself to produce more and more leafage, it is because by its nature it must, and not because it obstinately shuns fruit-production. In every plant a perfect balance is maintained between leafage and rootage. These are interdependent. The roots absorb and send up to the leaves a certain amount of food-materials. These the leaves take and use in the manufacture of food, which in turn passes downwards and is used to build up additional tissue in the roots.

The more root, the more food-materials; the more food-materials, the more leaves required to deal with them; the more leafage, the more food sent down to the roots; and again we are brought round to an addition in the extent of rootage. Let the garden-worker disorganise the working of this perfectly balanced machine, let him remove part of the leafage by pruning, and at once the plant sets itself to develop more wood and leaves to enable the machinery to work under normal pressure. This is very well shown by Fig. 76. A strongly growing branch was cut hard back in autumn, and in the spring a multitude of hitherto dormant buds were forced into growth in order that their leaves might do the work of those leaves which had been removed. So that in the first place the cutting back of wood, with the consequent removal of leafage, must result in the growth of fresh wood upon which leaves develop. This is but the plant's method of maintaining a balance between roots and leaves.

Aims in pruning.—It will be evident, then, that pruning must be done with two distinct ends in view. In the first place, the plant must be trained to some required form, all growth which tends to depart from this being repressed; and secondly, the habit of wood-production must so far as possible be changed into one of fruit-production, and the size and quality of fruit improved. Generally speaking, all pruning is done for the sake of either, or both, these ends.

It is a simple matter to state generally the object of all pruning operations, but when it comes to giving particular directions for each tree or variety of tree and bush, difficulties arise, inasmuch as the treatment for each tree and bush varies largely with the special form into which the plant is trained, with the character of the plant itself, and also with the local conditions under which it is grown. Therefore no attempt will be made here to deal with the cases of individual plants, but throughout the discussion the aim will be to lay down broad principles of pruning, allowing the garden-worker to apply these principles to the plants under his care, modifying his treatment to suit special requirements necessitated by form and variety of plant and by the conditions under which it is being grown.

"To prune," the dictionary says, is "to trim by lopping off superfluous parts." Now the parts of a tree which from the fruit-grower's point of view may be considered superfluous are three in number—leaves, wood, and roots; and for each of these a special type of pruning is employed.

15. Summer-pruning.—Towards the end of June and in July, examine all apple trees for wood of the present year's growth which has no blossom-bud at the tip. In the case of leading or main shoots count six leaves from the base of the shoot, not counting the small basal leaves, and cut off the shoot with a pruning-knife (Fig. 62), at a point one-eighth of an inch above the bud situated in the axil of the sixth leaf. Side or lateral growths should be treated similarly, but should be cut back to three good leaves.

Should any of the buds left on the young wood begin to grow into shoots during the following months, these must be cut back again about the end of August, or the beginning of September.

The practice of summer-pruning.—In the months of June and July the heating effect of the sun is strongest, and during this period, as a rule, most growth is made by fruit-trees in Britain. The months of August and September, on the other hand, are the months of ripening of fruit, wood, and buds. Thus there comes a period when plant growth is at its height, when the ascent of sap in the plant reaches its maximum, and could we be certain of seizing this exact time for the work of summer-pruning, there would be little danger of our being unsuccessful in the operation. That is, the best time for this work is just when growth begins to cease.

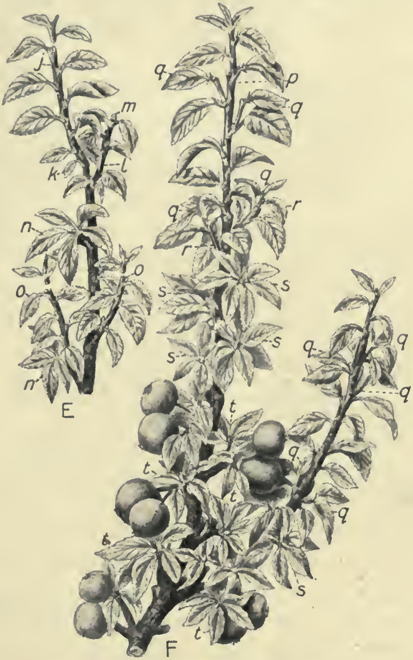


FIG. 79.—Summer-pruning apple shoots.

E. Portion of branch with characteristic growths. *j.* Extension growth pinched at the sixth good leaf, not counting small basal leaves (*k*); *l.* side growth not extending more than five or six leaves and terminated by a bold bud (*m*), generally a blossom bud; *n.* spurs (a short stubby growth, the leaves disposed in corona, with a prominent bud in the centre); *o.* growing side shoots pinched at the third good leaf.

F. Portion of branch in bearing. *p.* Extension; *q.* laterals (not to be pinched unless extending beyond three leaves); *r.* side growing shoots pinched; *s.* one-year spurs; *t.* two-year spurs.

The reason for this is evident. If a shoot be cut back while growth is still proceeding, at once the tree attempts to maintain the balance between rootage and leafage by the development of the terminal remaining bud. Should this occur, conditions are practically the same as though summer pruning had not been done. On the other hand, should pruning be delayed until the leaves have ceased to function, the pruner might just as well have allowed the shoot to remain until the time for winter-pruning, for by cutting it back he is in no way influencing the immediate development of the branch.

Now suppose a shoot has been cut back at just the correct time, *i.e.* when growth is beginning to cease. Sap is still ascending, but with decreased vigour. Consequently less leafage than the plant possesses may be made to perform the function of food-manufacture. Some leaves are cut off, and in the process wood is removed. The result is that less wood remains to receive the food which the leaves manufacture, and therefore this remaining wood will be better ripened, as it has more food at its disposal than when the whole shoot remained on the branch. More food thus will be directed also towards the already formed fruit, which is consequently improved in quality, while the buds also are better fed and swell out with stored-up substances.

In addition, sunlight and air, the other requisites for the ripening of both fruit and buds, have freer access to all parts of the plant upon the removal of leafage.

Summer-pruning must not, however, be overdone; hence the advice to cut back main shoots to six buds and laterals to three. The removal of leaves if carried to excess may result in diminished food-manufacture to such an extent that the tissues of fruit, branches, and roots may be impoverished by lack of food and the strength of the plant thus much reduced.

16. Winter-pruning.—In December, January, or February, examine the tree for growths which tend to grow inwards towards the centre of the plant, and cut these back to two buds, or cut them out at the base according to their position. Do any shoots cross each other, or are any too close to each other? If so, cut one out at its base. Cut back all summer-pruned laterals to two buds. Cut back all weak growths also to two buds. Should the terminals have made any growth since summer time, cut them back to six buds; or should the sixth be pointing inwards towards the centre of the tree, cut back to the fifth, so that subsequent growth may be outward and upward.

Remove all decayed pieces. Thin out fruit-buds (Fig. 85, *B* and *C*).

The practice of winter-pruning.—The centre of the plant is kept as open as possible, so that by full entry of sunlight and passage of air, every shoot left on the tree may have full opportunity of being brought to bearing point.

The same reason applies to the cutting back of terminals to an outward-pointing bud. A weak shoot is cut back to two buds, so that the whole of the food-materials which formerly supplied the whole shoot may thus be concentrated upon only two buds, with the result that these will grow out more strongly than they otherwise would do.

The above treatment is suitable for a well-established tree which is in bearing condition (Fig. 84), and treatment as similar as possible should be given each year. Otherwise hard pruning may be necessary, and too often the result will be somewhat like that shown in Fig. 76. In every case only about an eighth of an inch of wood must be left above the top bud retained, for, as it possesses no leaves to manufacture food with which to build up its tissues, all such wood left upon a shoot must die back. Should a long piece be allowed to remain, the decaying tissues present an excellent opening for the entrance of fungi and insects, whose action will result in disease.

17. **Root-pruning.**—Should any tree in the fruit-plot put on much wood each year and bear little or no fruit, it must be root-pruned. This should be done in November, *i.e.* the period of most marked inactivity. If the tree is a large standard it should be but half root-pruned in one year, the remaining half being treated in the following November, for fear of the tree being blown over in winter. All wall- and wire-trained trees may have the whole of their roots pruned in one operation.

Dig a trench about 2 feet wide and 2 feet deep right round the base of the tree, the inner edge of the trench being 2 to 3 feet from the trunk. All coarse roots met with should be cut back to the inner edge of the trench, as already advised in the treatment of planting trees. Then work inwards with the spade towards a point under the trunk of the tree, keeping 2 feet beneath the surface. Again cut away all strong roots, especially those which have a tendency to downward growth, and examine carefully for any signs of a tap-root. This latter should be severed within 6 inches of the base of the trunk if possible. Now replace the soil, but bring nearer to the surface all roots which have a tendency to downward growth, and pack the earth as tightly as possible around the roots.

The practice of root-pruning.—Root-pruning may be practised for two reasons. First, to restrain the over-production of wood; and, secondly, to enable a grower to have a larger number of trees in his garden than is possible without this operation.

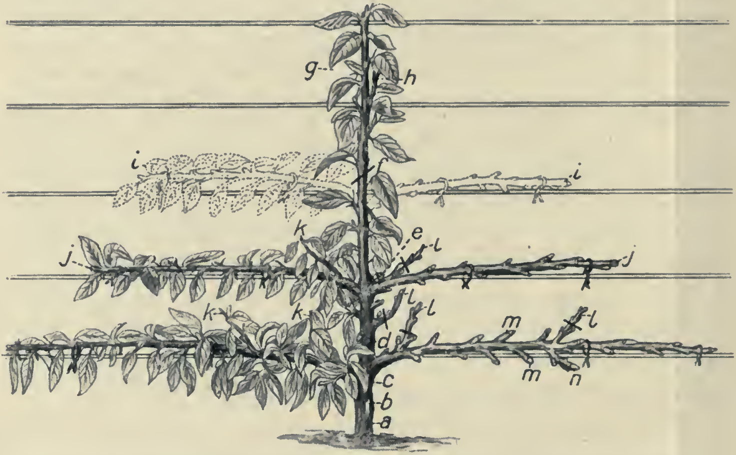


FIG. 80.—Pear tree horizontally trained. One side of the tree is shown in leaf and the other side bare.

a. Stock; *b.* point of budding or grafting; *c.* scion or variety of pear; *d.* point of heading maiden tree; *e.* point of second shortening; *f.* point of third (prospective) cutting back; *g.* leading or stem growth with laterals (*h*) pinched; *i.* side branches (prospective); *j.* one-year side shoots or branches; *k.* laterals pinched; *l.* laterals marked for shortening; *m.* spurs with blossom buds; *n.* short shoot with bold bud at the extremity, generally a blossom bud (not to be shortened).

At the outset the grower must be reminded of a fact already insisted upon, *i.e.* that perfect balance is naturally maintained by a tree between its leafage and its rootage. Therefore it is evident that if a tree is making much growth of wood, no amount of branch-pruning will result in the production of less wood and therefore of fruit.

The natural inference, then, is that the only method of restraining this tendency towards wood-production is the reduction of the roots. This results in a decrease in the amount of food-materials passed upwards from the roots, as the absorbing surface of these has been reduced. Thus the leaves receive less food-materials to work with; as a result less food is manufactured, and consequently there is less increase in length. Now checked growth in length is usually accompanied by fruit-bearing, so that this operation of root-pruning directly induces the production of fruit.

But just as in the case of branch-pruning, the injured part of the plant tends to develop those very parts of which it has been deprived. A cut-back branch puts on growth from the remaining end bud. Similarly a cut-back root develops a host of minor fibrous adventitious roots which arise from behind the point of cutting. Naturally, then, after one or two years the tree tends to return to its former conditions, just as in the case of branch-pruning, and consequently if root-pruning is to be effective it must be performed every two years at least.

When root-pruning is resorted to for the purpose of keeping the roots of a tree from encroaching upon the territory of neighbouring plants, the operation is usually performed yearly, especially if the space of ground available be small. Thus the roots of the tree are restricted in narrow compass, a circular area about 3 feet in diameter being the usual space. Every cubic centimetre of the soil in this region is in close contact with the fibrous roots of the tree, and the result is that the food-materials at the disposal of the plant quickly become used up. Thus the application of liquid manure and top-dressings of manure are necessary in such a case, and annual root-pruning is imperative, chiefly with the object of thinning-out, so that too many roots may not compete for the available food-materials.

So much for trees which are already established. The student, however, is dealing with but part of the subject if his operations are confined to such plants. For a full understanding of the principles of pruning he must take a share in training trees from their earliest stages.

If the fruit-plot has been stocked with trees as already advised, the student will have trees one, two, three, and four years old at his disposal upon which to carry out the following operations.

18. First year.—In December examine a "maiden" tree (Fig. 81), *i.e.* one which has made one year's growth from budding or grafting, note the position of the junction of the stock and the scion, count six buds upwards from this point, and pass the pruning knife through the stem in a slanting direction one-eighth of an inch above the sixth bud. If the tree is to be grown as a cordon on a wall or fence, the top bud retained should be on the front of the stem, in which case the fourth or fifth bud may be the more suitable to retain.

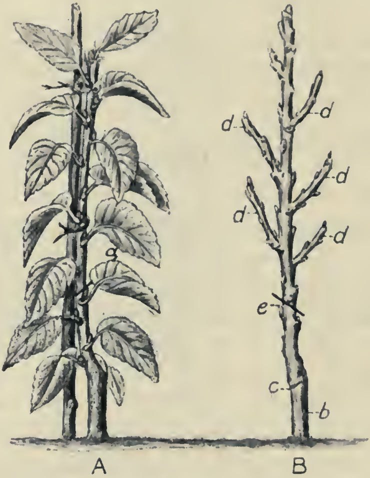


Fig. 81.—"Maiden" trees.

A. Sturdy tree in growth, not pushing laterals. *a.* Point of shortening at winter-pruning.

B. Strong growing tree with laterals. *b.* Stock; *c.* junction of scion (apple) with stock (English Paradise); *d.* laterals; *e.* point of shortening for bush form of tree.

19. Second year.—In spring, the buds retained will spring into growth. Subsequent treatment depends wholly upon the type of tree desired. For a cordon (Fig. 70) the growth of the top front bud must be encouraged, the other shoots being pinched back to three leaves as they grow. If a bush form is what is desired, three buds should be chosen springing out in different directions, so as to form a symmetrical plant, the others being rubbed off. For a tree similar to that shown in Fig. 80 the top front shoot must be encouraged, and two others as well, which are growing out at right angles to and in the same plane as the leader. If a pyramid-form (Fig. 74) be wanted, the growth of the leader is also required, together with the development of at least three others. On all the shoots which are permitted to grow as leaders, count six good leaves from the origin, omitting any small basal leaves, and pinch back any lateral growths above this to one leaf, as they grow in summer (Fig. 82).

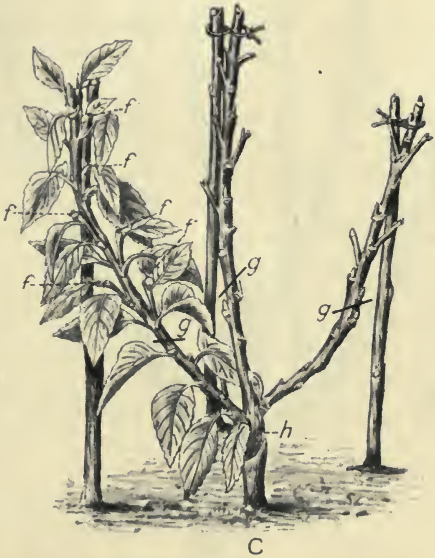


FIG. 82.—Second year's tree.

C. Tree **B** (Fig. 81). *f.* Laterals pinched to one leaf as they grow, *i.e.* summer-pruned; *g.* points of shortening at winter-pruning; *h.* Stem from which all growths but the three shown have been removed at an early stage of the year's growth.

In December examine the growths. Cut back, to about six buds from the base, all the branches which have been allowed to grow, the top bud retained in the case of cordons being on the opposite side of the stem to the bud from which growth began in spring. Thus the stem will be kept straight. In the case of any other form where straight growth is desired, the same method should be adopted. Bush and pyramid-shaped trees should have their branches cut back to a bud which points outwards from the centre. This keeps the interior of the plant from becoming crowded.

20. Third year.—The buds retained will begin to grow in spring. Shoots which are to develop into leaders—about two to each branch in the case of bush-formed trees—should be permitted to grow well, but any side growths above the sixth bud from the origin of the present year's growth should be pinched out to one leaf. Side shoots from wood of the previous year should be pinched back to three good leaves as they are made.

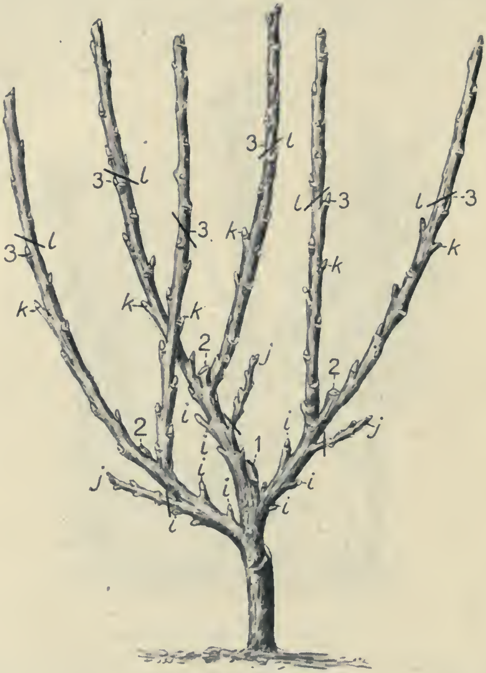


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Fig. 83.—Third year's tree.

D. Tree **C** (Fig. 82). *i.* Spurs (stubby shoots with rounded bud) not to be shortened; *j.* side shoots not required for forming branches, stopped during growth in summer at the third leaf (not counting small basal leaves), and cut back at the winter-pruning to a couple of buds as shown by the cross-lines; *k.* spur-like buds (sometimes blossom buds), otherwise forming spurs the following season; *l.* points of shortening. The numerals indicate years of growth and pruning.

In December, main branches should be cut back to six buds of the present year's growth, just as before. Side spurs on the previous year's wood should be pruned to two good buds, any spurs which have formed flower-buds being wholly retained. All side secondary growths in the case of bush or pyramid-formed trees which have a tendency to grow into the centre of the tree should be cut back to two buds, while, if they are growing too closely, a few should be wholly removed.

The training of fruit-trees.—The third year's work is fairly representative of the method of pruning in the succeeding years (Fig. 84). One point, however, requires remark. In ordinary circumstances strong growth should be pruned lightly, *i.e.* should have but a small fraction of its length removed (for reason see Fig. 76), while weak growth should be pruned hard, *i.e.* to two buds or so, so as to throw into these the whole supply of food-materials which the shoot receives, thus ensuring strong growth. In certain circumstances, however, it is necessary to prune strong growth hard, and weak growth lightly. Should a strong branch develop in a direction contrary to the form of tree desired, it becomes necessary to restrict its growth so as to throw strength into a weaker shoot whose development will conform to the special type of tree. In such a case the strong shoot must be cut back to a quarter or less of its length, while the weak shoot merely has its tip removed.

What has been attempted here is to discuss the broad general principles of the pruning of fruit-trees, allowing the student to work out the treatment in particular cases for himself. In this he will be assisted considerably by a careful examination of the drawings and notes of Figs. 79 to 85.

Gooseberries.—An examination of a gooseberry branch, as already advised, will show that no fruit is borne on the present year's growth, nor does fruit develop on very old wood. All the other parts of the plant bear fruit-buds or fruit-spurs. It will be found in late summer that the best fruit is borne on wood which is one year old. Therefore, one or other of two methods, or a combination of both, may be adopted. The bush may be pruned, as is the apple tree, so as to further the development of fruit-spurs; or long shoots may be encouraged, merely the tips being cut back. If the bush form be adopted, care must be taken

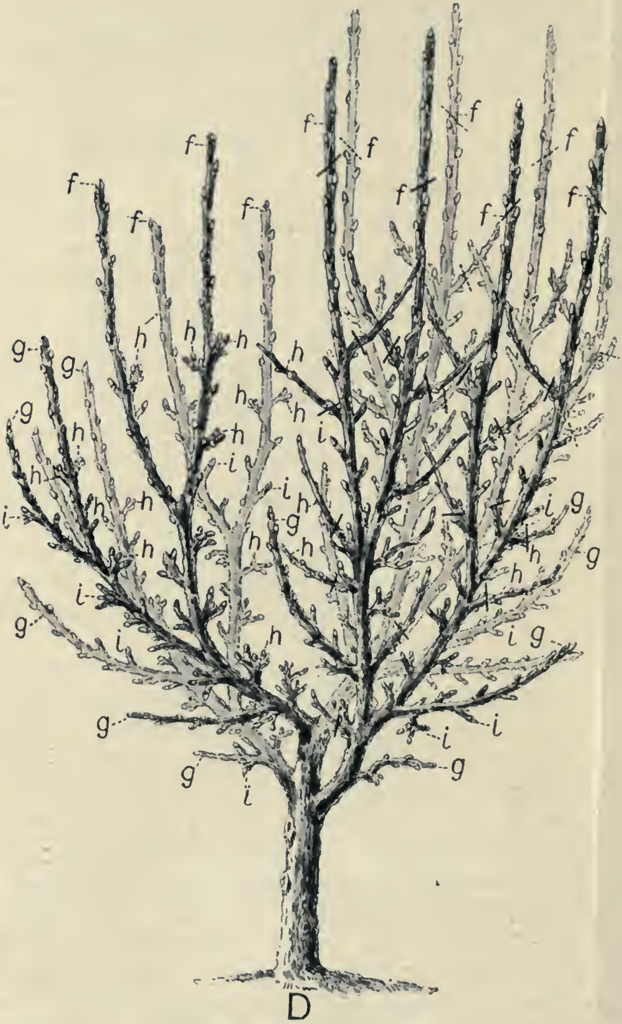

FIG. 84.—Pruning an apple tree.

Left hand side of tree is pruned; right hand side unpruned, but marked for shortening by cross lines. Back branches are shown in faint outline for clearness.

f. Extension growths shortened or marked for shortening by cross lines, in order to induce buds to start into growth on the whole length of the previous year's wood; *g.* short extensions to be left intact; *h.* shoots which were summer-pruned and shortened to two buds at winter-pruning; *i.* fruit-spurs.

to prune the leaders to a bud which points upwards, or otherwise a trailing method of growth will result, with consequent spoiling of the berries as they rub upon the soil.

As the gooseberry plant is partly a spur-bearer, it responds to summer-pruning. This should be restricted to the pinching out of the tips of terminal shoots. As these are the parts especially favoured by green fly, this operation lessens the danger of this pest.

Black-currants.—As has already been found, black-currants bear best upon wood of the previous year's growth, few blossoms developing on older wood. Therefore, little pruning of young wood is required in this case. Pinching out the tops in December is all that is needed. By and by, however, old unprofitable wood must be boldly cut out to encourage the growth of young wood. This should be begun from the centre of the bush.

Red-currants will be found to bear similarly to gooseberries, and should be treated in the same manner.

Raspberries bear upon canes of the previous year's growth. Therefore all old canes should be cut off and burned immediately fruiting ceases. In this way strength is thrown into the young wood, and many insect pests are destroyed. Fruit is borne by this plant on lateral shoots which develop from the canes which grew out in the previous season. Therefore the main shoots may be cut back in spring to a suitable height, so as to encourage side growths. This height will depend upon the method of growth adopted.

Weather observations.—Perhaps no part of garden-work demands closer attention to weather conditions than fruit-growing. Over and over again we hear of much damage done to fruit-trees by a night's frost, or by a cold dry east wind in spring; but usually the growers who have suffered are those who have made no provision for such emergencies. The times of most danger, perhaps, are the periods of young buds and of blossom, and the localities which suffer most are inland regions and sheltered spots. The cause of this is that a mild period in spring causes the buds to burst early into growth. So long as they remain dormant the buds are in no danger; immediately they sprout they are open to many enemies, and the mostly deadly of these are cold winds and frost.

Fruit-gardens on the sea-coast are, as a rule, later in beginning growth than inland gardens. The increasing warmth of the sun heats up land which is remote from the sea, while in spring the ocean is still cold and prevents the heating up of the land in its

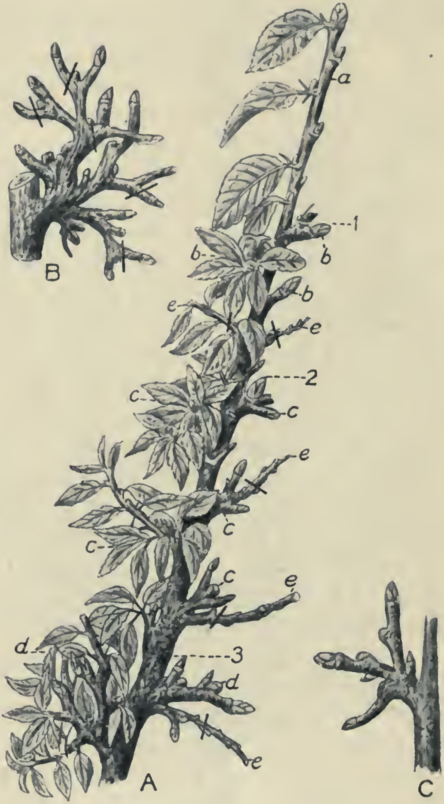

Fig. 85.—Pruning apple-spurs.

A. Portion of a branch. *a.* Extension growth terminated by a blossom bud (as common with Irish Peach, Lady Sudeley and Golden Noble); *b.* one-year spurs with blossom buds; *c.* two-years spurs; *d.* three-years spurs; *e.* spur growths pinched to three leaves in summer and shortened in winter to the cross lines.

B. Branched spur marked for thinning.

C. Spur with long stragglers cut off. The spurs are thus kept close to the branch.

proximity. Thus buds burst into leaf inland while trees are still dormant along the sea-coast in the same latitude. But April—May even in most years—brings frost and cold winds, with the result that trees growing inland have their buds and blossoms nipped when those on the coast have not yet burst into growth.

In addition, as the season advances there is much variation in the temperatures inland between day and night. Soil which is warmed rapidly radiates its heat rapidly at night, and thus inland plants are subjected to great variations of temperature. Along the sea-coast, however, the ocean, which radiates its heat much more slowly than the land, prevents the soil in its proximity from falling to a very low temperature at night time. To all this must be added the dangers of cold, dry winds and frosts. Consequently it is evident that some provision for such contingencies must be made by the fruit-grower.

21. The first thing to do is to endeavour to foretell the possible occurrence of such killing colds and frosts. In this the student will be helped by the weather observations he has been taking constantly throughout the year ; but for good fruit-growing even more certain signs are necessary. Much use in this connection may be made of the readings of the wet- and dry-bulb thermometers. The method is explained below. The accompanying table (p. 256) has been compiled from that in use by the United States Weather Bureau, and may be taken as sufficiently accurate to enable the possibility of a night-frost to be foretold if readings be taken between 4 and 5 p.m.

Thus if the reading of the dry bulb be 50 deg. and that of the wet bulb 45 deg., there is a difference of 5 deg. On the left-hand side of the table will be found the figure 5 under the heading "difference of reading of wet and dry bulbs." Opposite 5 under the heading 50 deg. will be found 40. This means that should the air be cooled to 40 deg. dew will be formed. The following method of calculation must be adopted for readings intermediate between those given in the table. When the dry bulb thermometer registers (say) 62·5 deg. and the wet bulb 56·5 deg., the difference is 6 deg. 62·5 deg. is not given in the table, but 60 deg. and 65 deg. are both found, and for a difference of 6 deg. these read 49 and 55 respectively. Now 62·5 deg. is half-way between 60 deg. and 65 deg., so that dew-point for 62·5 deg. will be midway between 49 and 55, *i.e.* 52. Other readings may be worked out similarly.

Dew-point Table.

Diff. of reading between wet and dry thermometers.	Temperature of Air—Fahrenheit.															
	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
1°	11	17	22	27	32	38	43	48	53	58	63	69	74	79	84	89
2°	6	13	19	25	30	35	41	46	52	57	62	67	72	77	82	87
3°		8	15	22	28	33	39	44	50	55	60	66	71	76	81	86
4°			11	18	25	30	36	42	48	53	59	64	69	74	80	85
5°			5	14	22	28	33	40	46	51	57	62	68	73	78	84
6°				9	18	25	31	37	43	49	55	61	66	72	77	82
7°				2	13	22	28	34	41	47	53	59	64	70	75	81
8°					8	18	25	32	39	45	51	57	63	68	74	79
9°					1	13	22	29	36	43	49	55	61	67	72	78
10°						8	18	26	33	40	47	53	59	65	71	77
11°						0	13	23	30	38	45	51	57	63	69	75
12°							8	19	28	35	42	49	56	62	68	74
13°							0	14	24	32	40	47	54	60	66	72
14°								9	20	29	37	45	52	58	64	70
15°								1	16	26	34	42	49	56	62	69
16°									10	22	31	39	47	54	61	67
17°									3	18	28	36	44	52	59	65
18°										12	24	33	42	50	57	63
19°										5	20	30	39	47	55	62
20°											15	27	36	45	53	60

Now the point to observe here is that when dew-point and freezing-point coincide, plants must suffer from frost. Thus when dew-point is close to 32 deg. at night-fall, the garden-worker should make provision for the protection of his fruit-trees. As a rule, readings cannot be taken by the student much later than between 4 and 5 p.m., and should the dew-point be within 10 deg. of freezing-point at that time, *i.e.* should dew-point be 42 deg. or lower, then protection must be given. Otherwise there is little fear of harm from frost. Sacking nailed on to stakes affords sufficient protection.

CORRELATED EXERCISES.

1. Why should fruit-trees and bushes, in fact all perennial plants, be planted in November?

2. How is it that early varieties of trees in mild districts suffer most from frost? For a mild locality subject to late April and May frosts, would you plant early or late varieties? Why?

3. Account so far as you can for the fact that the district around the St. Lawrence lakes in Canada is famous for fruit.

4. Examine the remains of a frost-nipped blossom. Does the mere fall of the petals prevent the development of fruit? What more important parts are shrivelled? Show how this prevents the growth of fruit.

5. Why should trees not be winter-pruned until the leaves have fallen?

6. Explain why trees which have been grown very close together in the nursery should not be chosen by the buyer.

7. How is it that the Isle of Wight in January has the same average temperature as Stornoway, while in July the temperature of the former is about 62 deg. and of the latter 55 deg.—a difference of 7 deg.? The annual rainfall of the former is about 28 inches, of the latter 50 inches. Account for this. What influence will these factors have in determining the agricultural pursuits of the people in each district?

8. Trees do not grow beyond a certain height on mountain sides. Why? Why are they found at higher altitudes on the south slopes of the Alps than on the north slopes?

9. Describe the processes which precede the fall of the leaf in the case of trees growing in cool-temperate climates. Of what benefit is such fall to trees?

10. At no period in their life are the trees in the Amazon forests leafless. Account for this. How then do the trees obtain a period of rest?

11. Account for the comparatively great fall of temperature at night in most deserts.

12. State exactly on which parts of the following plants fruit is borne: apple, pear, black currant, red currant, gooseberry, raspberry.

13. Describe alternative methods of pruning gooseberry plants. Give reasons.

14. Describe the evils which usually result from tying a branch of a tree tightly to a wire in spring and leaving it thus throughout the season.

15. What benefits result from summer-pruning?

16. What benefits result from winter-pruning?

CHAPTER XIII.

DISEASES OF PLANTS.

1. What is implied by the word "disease"?—In summer, search the school garden and any other garden to which you may have access, and obtain as many as possible of the following: a cabbage plant whose leaves are wilted and hanging limp; a cabbage plant leggy and run to length (search the seed-bed for this); a sweet-pea plant which has been supplied with too much water and liquid manure, and has run to leaf and stem rather than to flower; a rose branch attacked by mildew (you will recognise it by the limp appearance of the growing shoot, which is covered over with a whitish material); the stem of a potato plant which is attacked by potato disease (for description see page 267); a radish plant which is growing on very shallow soil and has had no attention given to it with regard to moisture.

Examine each of these in detail while it is still fresh, and describe as minutely as you can the points wherein the plant, or part of a plant, differs from a healthy growing specimen of the same variety. Examine the whitish matter on the diseased rose-spray, and a piece of a leaf of the diseased potato plant under the low power of a microscope, or under a magnifying glass. Describe what you see, giving as many details as possible.

The healthy growing plant.—A healthy plant is in the first place a most delicately constructed machine, whose parts are stimulated into action by energy derived from the sun, and whose working is directed towards the manufacture of food from substances absorbed from the atmosphere and the soil.

In the second place, it is an organism possessing vitality, which vitality is inseparably connected with strength derived from this manufactured food.

Tendencies towards unhealthiness.—Therefore it must be evident that any variation in the natural growth of the plant, which either prevents the passage of food-materials from the atmosphere or from the soil, or results in an overabundant supply of these, or which prevents the appropriation of the energy of the sunlight, or causes an over-supply of this to be available, must result either in a deficiency or in a superabundance of food. The consequence of this is that the vitality of the plant either must be impaired or rendered too vigorous in one special direction. Or, again, any outside agency which, when the food has been manufactured in the leaves, appropriates this prepared food for its own use, thus robbing the plant-machinery of the fuel it requires for perfect working and clogging up those parts of the machine whose function it is to manufacture more food, must also result in impaired vitality in the plant.

This lowering of vitality is in each case the result of a decrease in the supply of food, certain amounts of which each plant requires if it is to exist as a living plant whose machinery is in full working order. But it can scarcely be said that the plant in any of the above conditions is diseased yet. All that can be insisted on safely is that its vitality is so low that its power to resist the attack of any enemy now is decreased greatly, and given the accidental breaking away of a branch, a rupture on the stem, in fact a wound of any kind, it is extremely unlikely that the plant will have the power to protect itself, as in ordinary times, by the rapid closing up of the wounded part.

Still more, should one or other of the thousands of fungi which exist in every garden find entrance by this open wound, the plant-machinery is working so weakly and with such great difficulty that the growth of the fungus clogs the machine, and decay of the plant tissues sets in as the fungus feeds upon and breaks up the food in the plant. These tissues are not built up again, since further food is not being manufactured as the machinery is out of order; and disease ensues, often followed by premature death.

The plant and its enemies.—Thus it is evident that one alone of these factors is not sufficient in itself to cause disease in a plant. A fungus, for example, may have no chance to attack a normally growing plant, nor indeed can the same fungus attack all varieties of plants even though they be unhealthy. Just as the black-currant mite is unable to establish itself upon a cabbage, so the fungus of the potato disease cannot live upon the tissues of (say) the bean or the pea.

Each fungus requires a certain nature of food upon which it can feed, and lacking this special quality of food it fails to develop. The fungus of the potato disease, for example, finds conditions unfavourable should it alight upon a dandelion, and therefore is forced to change its form or die. Not only has each fungus certain requirements with regard to the food-substances which are suitable to it, finding these only in the case of certain plants, but even these special plants must be each in a certain condition with regard to its vitality and the general working power of its machinery, and therefore with regard to the nature and quality of the food being formed in its tissues, ere the fungus finds the exact type of food which permits it to live and grow.

Distinction between disease and cause of disease.—It is evident from the above that the cabbage butterflies, the currant mite or the fungus *Phytophthora* (which causes potato disease), cannot really be termed diseases in themselves. They are in fact living organisms, animals or plants, which in consequence of the injury they cause by feeding upon the food contained in certain parts of the plants, bring about disorder in the machinery of the plant. This results in "dis-ease," *i.e.* lack of ease, in the working of this machinery, thereby directly hinders the manufacture of food, and indirectly results in the impaired vitality and possibly the premature death of the living plant. In other words, they are the *causes* of certain forms of disease or disorder in the plant, and this disorder is evidenced by a type of growth which departs from the ordinary development of root, stem, branch, leaf, flower, or fruit, and thus may be termed abnormal.

Note that abnormal growth is merely, as a rule, *evidence* of the disease, and is not the disease itself. The latter is much more deeply rooted, having its seat in the very tissues of the plant. For example, the brown spots on the leaves of a diseased potato are not the disease, they are but evidence or symptoms of the disease. The disease or disorder is seated in the cells of the leaf, stalk, etc., where the fungus is breaking up and feeding upon the starchy food manufactured by the leaf.

To sum up, we have found that disease or disorder in the plant is really a result, and must therefore have a cause. This result is evidenced by certain abnormal modifications of growth which we shall call *symptoms*. So that to study any disease it will be necessary first of all to examine the symptoms as shown by the living plant, then search for a cause or causes; and should we wish, as we certainly shall, to apply something which will act as a deterrent to this disorder, we shall have to search for remedies which have as their object either the destruction of the cause of the disease, or the rendering of conditions so unsuitable for the maintenance of the life of the animal or plant causing the disease, that it is placed at decided disadvantage for the perfecting of its vitality, and thus has a much lessened influence upon the plant which is being attacked.

2. Symptoms of disease seen in the general appearance of the plant.—Examine the crops in the garden, first of all viewing the plant as a whole and looking for cases of the following: (1) where the plant has run to length accompanied by paleness in its parts, (2) where the plant is stunted, (3) where abnormal growth of any of the parts is evident. Examine each of the plants chosen, note the location in which it grew, the type of the soil from which it absorbed food-material, and the presence of any foreign bodies which might occasion departure from the normal type of growth.

Disease shown by the general appearance of the plant.—If the row of peas sown thickly in the experimental plot be examined before midsummer, there will be little difficulty in finding plants which have run to length, the lower parts of which have lost their green colouring matter and have taken on in summer the yellow tint of autumn. This is accompanied in many cases by long internodes and leaves smaller than the ordinary.

The cause is not far to seek. Owing to overcrowding, the plants have individually received but a small amount of sunlight. Thus the formation of food did not proceed as rapidly as the plant absorbed materials from the soil, and food-starvation of the parts followed, together with lack of formation of chlorophyll. As a result the plant machinery became deranged, and certain functions were not performed; in other words, disease set in.

The opposite kind of growth, *i.e.* a stunted type of plant, is usually to be found on soils which are shallow and supplied but poorly with moisture. But an even more frequent occurrence is the arrest of growth when the plant is still in its young stage. The cause of this will be found usually either in that part of the stem which is underground, or in the root, where some animal is feeding upon the plant tissues, thus preventing the ascent of soil-moisture to the stem. The result is that the amount of food manufactured in the leaves is very small compared with the ordinary food-requirements of the plant, and therefore the plant ceases to put on increase of length. Such a condition of things will often be found in the case of a cabbage plant attacked by the cabbage root-fly (Fig. 89).

The arrest of growth, however, may be evident in but one special part of a plant, *e.g.* in the buds. A case in point is black-currant bushes attacked by the black-currant mite (Fig. 95). In this case the food-material does make its way upwards in the plant, but owing to the irritation of the tissues of the buds and on account of the fact that the food in these tissues is being used up by the mites, the buds are unable to develop, and the greater part of the plant may be leafless. Diminution of leafage results in additionally decreased vitality, and, if permitted to persist, may cause premature decay of the bush. Abnormal growth is more common either on underground parts of the plant or on that part which is just at the surface of the soil. Galls, tumours, scab are all instances of this.

3. **Symptoms of disease as seen on leaves.**—Search the growing plants of the garden for leaves which show the following characteristics: (1) yellowing, (2) wilting, (3) spots or blotches (these latter may be of different colours according to the type of plant and also according to the cause).

Examine the moisture conditions of the soil in which the plant grew, look for the presence of foreign bodies in or around stem and root; place some of the substance of which each spot consists under the low power of a microscope, examine, and note what you see.

Disease shown in the leaf.—One of the most common of abnormal appearances in the garden is the yellowing of the leaf, and this very often is accompanied by wilting, or drooping, of the parts. The cause is that transpiration is proceeding at a rate greater than that at which moisture is being supplied by the roots. This does not necessarily imply a lack of moisture in the soil. It is very often a sign that full use is not being made of soil-moisture, and examination will usually show that some foreign body has so obstructed the organs of the plant which collect or distribute this moisture that its ascent is hindered.

Wilting alone may result from careless exposure of the roots, as in the case of a potato plant during earthing-up operations, which is followed by decreased moisture-absorption; or, again, the cause may be an insect or a fungus. The honey-dew excreted by green fly in a short time so completely closes up the stomata of the leaves of a rose shoot that, while there may be a sufficient supply of moisture, yet the food-materials cannot be made use of, as carbon-assimilation from the air cannot proceed. Somewhat similar results are brought about by the insect which excretes the white foamy substance commonly called cuckoo-spit. In addition, both green fly and the insect above mentioned are increasing the loss of moisture from the leaf as they suck the sap of the plant.

Spots or blotches are usually the result of the attack of fungi, which in almost every case feed upon the plant tissues, thus reducing the available amount of food. Some, however, are merely surface wounds, *e.g.* insect bites, etc., which have healed up. In cases where browning begins at the tips of the leaves, it will usually be found that drought is the real cause. This is especially true in the case of grasses, a large number of which are very shallow-rooted and quickly exhaust the moisture-content of the surface layers of the soil.

4. Symptoms of disease as seen on the outer skin or bark.—Examine the stems, branches, and twigs of the vegetables, flowering plants, and trees in the garden, looking for (1) ruptures in the outer skin or bark, (2) places where the outer skin or bark is gradually being eaten away. Note the conditions with regard to moisture under which the plant is growing in the former case, and by examination with a pocket lens attempt to find out the cause of the latter.

Disease shown in the outer skin or bark.—Rhubarb abundantly supplied with liquid manure often has its tissues so distended with moisture that the outer skin bursts and a gummy substance oozes out through a wound which the plant is evidently incapable of healing. Turnips also in very wet weather are subject to a similar bursting of the outer skin.

But even in ordinary weather, where plants are overcrowded, and extend their growth this way and that towards the light as their neighbours in turn overshadow them, these movements result in twistings of the stems with consequent rupture of the bark. Each of the above results in decreased vitality in the plant, as the passage of food-material or of food is obstructed and much lost. An even worse result, however, is only too common, namely, the attack of fungi, an instance of which will be found discussed under the heading of "apple canker" (p. 279).

5. **Symptoms of disease as seen in the fruit.**—Examine the fruit on your trees and bushes, looking for (1) signs of fruit falling prematurely, (2) spots or blotches on the outer skin, (3) malformation of any kind. Look for the presence of insect life, etc., which might account for any of the above.

Diseases shown in the fruit.—In almost every case the cause of disease in fruit is either an insect of some kind or a fungus. When an apple falls prematurely, a small hole, often partly covered over by brownish corky skin, will be noticed upon the fruit, and if this be followed inwards it will be found to lead to the core of the apple where a grub and the substances it has excreted will be seen. It has sustained life by feeding upon the tissues of the fruit.

Spots of different colours may be due either to insect or fungus attack, and only examination will enable the student to decide which is to blame. Indeed, the enemies of fruit are so many and so varied that the subject might with profit be discussed much more minutely than is possible in a general volume on school gardening.

Types or causes of disease.—In the above discussion it will be noted that in almost every case the disease, where it was not due to special conditions of soil or situation, was caused either by an animal or by a plant, an insect representing the former and a fungus the latter in each case. It is, therefore, necessary to examine each of these with a view of finding out the special method in which each attacks the plant.

Thus we are able to arrive at a knowledge of the weak points of defence in the structure or life-history of each, and weak points having been found we must devise means of attack peculiarly directed against these, each method of attack being especially suited to break down defences at the point of least resistance and bring death to that which causes the disease.

6. Insect pests.—Examine the action of the caterpillar of the large or the small white cabbage butterfly as it feeds upon a cabbage leaf. Does it bite the leaf? If so, note the method adopted. Were poison placed upon the upper or lower side of the leaf, would the caterpillar swallow it as it feeds?

Note the method of feeding adopted by green fly on roses. Does the rose leaf decrease in size? Does the green fly therefore bite pieces out of the leaf? How do you suppose it feeds? Were poison placed upon the upper or lower side of the leaf, would it necessarily be eaten by the aphis?

It is impossible in the space available to enter into much detail here, but sufficient facts may be gathered from the above examination to show that all insects do not injure plants by the same method nor at the same stage in their development. The caterpillars of the cabbage butterflies, for example, bite the leaf, swallowing the outer skins as well as the inside tissues. The green fly, on the other hand, does not eat away the leaf. It feeds by means of a sucking mouth, piercing through the outer skin and sucking the sap from the interior tissues of the leaf.

Vulnerable points in insect pests.—Thus the caterpillars of the cabbage butterflies might be destroyed by placing poison on the leaves upon which they feed, but this is not done, of course, as it would be well-nigh impossible to cleanse the cabbage thoroughly previous to its being used for the table. Other caterpillars, however, *e.g.* those which attack gooseberry bushes early in the season, may be so treated, as a sufficient time elapses between application and the pulling of the fruit to allow the poison either to be washed away or to lose its effect by contact with the atmosphere.

On the other hand, such treatment would be almost futile in the case of green fly, for the outer skins of the leaf are never eaten by them. To poison the food of insects provided with a sucking mouth is practically impossible, but examination has shown that the vulnerable point in these insects lies in the outer skin of their bodies. They breathe by means of pores or spiracles, minute apertures situated on their outer skin and communicating inwards. If these can be closed, the living insect must die for lack of oxygen. Also, if matter which is poisonous to the insect finds its way inwards by these openings, death must ensue. Both of these results may be brought about. A strong solution of soft soap successfully clogs these minute pores, laying a film of soap right over them, and such a poison as tobacco water finds its way inwards by the pores, causing death in a short time.

So delicate, indeed, and so distended with moisture are the bodies of these insects, that owing to the thinness of their skin they will be killed instantly if dropped into water which is just too hot for the hand.

7. Fungoid pests.—Thoroughly soak a piece of bread in water and then place it in a closed box, or under a bell-jar, on a piece of damp blotting-paper. Leave it until it becomes mouldy. Examine the growths which appear by means of a pocket lens. Can you find some which have rounded heads placed on the top of thin white stalks? Examine these heads. Take a small quantity of this growth on the point of the blade of a knife and place it in a drop of water on a glass slide. Examine under the low power of a microscope. What has happened immediately this head was placed in water? Examine the oval bodies which have emerged.

Should potato disease appear in your district, obtain a few affected leaves, dip them in water, and place them upon damp blotting-paper under a bell-jar. After a few days a whitish growth will be very marked on the leaves. Examine portions of this growth as above. These are called **Fungi**.

Do these growths show signs of being able to move freely about as did the bacteria which you have already examined? Are they then animals? Seeing they produce spores which germinate, and are not capable of free motion, what do you judge they are? Do they show any signs of green colouring matter, or chlorophyll? What conclusion does this cause you to arrive at with regard to their capability of manufacturing food?

The fungus which causes potato disease.—We found at an earlier stage in our study of garden plants that the main purpose of most plants is to produce sufficient seeds, tubers, etc., to ensure a continuance of the species in the following season. Fungi also when growing under suitable conditions give rise to an enormous number of minute spores, which are comparable to the seeds of ordinary green plants and are so small that as a rule they can be seen only under a microscope: in fact, over 800 of the spores of the fungus which causes potato disease must be placed in a line ere the row measures an inch. These spores are borne by this fungus on whitish-coloured branches (Fig. 87), which can easily be seen on those affected leaves which were placed under a bell-jar.

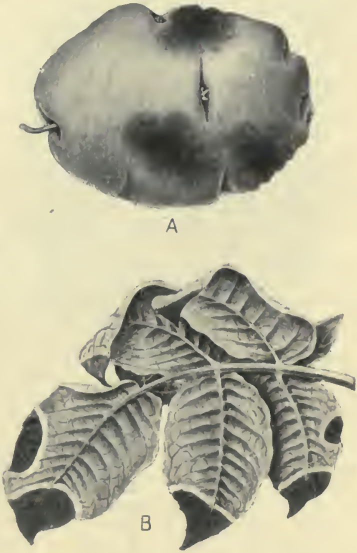

FIG. 86.

A. Tuber showing spots which are characteristic signs of potato disease.

B. Leaf from diseased potato plant. Note the dark-coloured, decayed portions and the whitish border which marks the progress of the fungus.

When viewed under a microscope, these branches will be found to be elongated cells from which side cells branch off at intervals and upon both of which egg-shaped spores are borne. It will also be noticed that these spores very readily break away from the branches, and as they are so exceedingly minute they are easily blown from their position by the slightest puff of wind. Thus the air in the vicinity of an affected potato plant becomes laden with these spores, a shower of rain carries down thousands of them, and they settle on soil and plants, here, there, and everywhere throughout the garden.

But as we have already found, that does not imply that each will grow. In the first place, just as the mustard seeds which were sown in air-dry soil and received no moisture (p. 6), failed to sprout and grow, so unless the spores of this fungus are supplied with water, they proceed no further in their development. Seldom, however, does the whole summer pass without a shower of rain; in fact, a night-dew gives them all the moisture they require, and germination quickly follows.

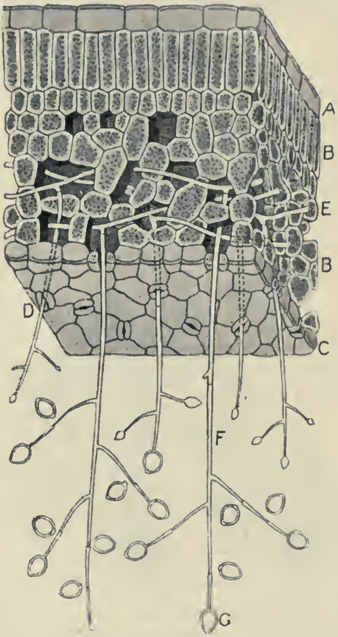

FIG. 87.—Section of potato leaf attacked by the fungus which causes potato disease. (Much magnified.)

A. Epidermis of upper surface of leaf.
C. Epidermis of under surface of leaf.
B, E, B. Cells which constitute the internal tissue of the leaf.
D. Stoma on under surface.
F. Whitish branches of the fungus bearing spores (**G**).

Having sprouted, the plant is prepared to continue its growth, but in order to grow it must have the necessary supply of food. Now this is a plant which does not contain chlorophyll, and therefore it is unable to manufacture food for itself from materials supplied by air and soil. Naturally, then, it appropriates such already-prepared food as it can make use of; but all plants do not provide just what suits this fungus. In fact, upon only one garden plant, namely the potato, does it find the food it needs, and once established it usually flourishes as long as the supply is maintained.

When the spore has sprouted on the leaf of a potato plant, each fungus sends out a long root-like growth, the purpose of which is to find its way into the interior of the leaf. Unless it accomplishes this, the plant must die for lack of food.

So many are the pores on the under side of an ordinary leaf, however, that usually the young fungus has no difficulty in finding entrance to the leaf through one of these, and once inside, it is in the midst of abundance of food suited to its requirements (Fig. 87). Accordingly it uses this food for the building up of its own tissues, and as a result the fungus grows with great rapidity, a whitish border of germ-bearing branches (Fig. 86) marking its progress as the "roots" of the plant push their way further and further into the tissues of the leaf and feed upon the built-up substances of which the leaf is composed. Thus they clog the plant machinery, and produce first of all disease or disorder, and later premature death in that part of the plant upon which the fungus feeds.

Nor does the fungus restrict itself to the leaves of the plant. In the stem also it finds suitable food, and, passing downwards, the roots of the fungus feed upon the tissues which they find there, obstructing the machinery of the stem to such an extent that it blackens in decay. The result is that the formation of tubers is arrested, as little new food is being manufactured in the leaves, and of this little but a very small amount can find its way downwards through the obstructed and broken-up passages of the stem. Thus there is no surplus to store up in the form of tubers.

Not only so, but the fungus finds suitable food in the tubers themselves, and as this plant does not depend for life upon the presence of air, it bores downwards through the tissues of the stem and finds its way into the underground parts. Here it attacks the starch grains and uses up part of them, so obstructing the passages in the tuber by breaking up the substances of which it is composed that the grains become blackened and decay sets in (Fig. 86). This decayed substance is quite unfit for food, and thus the crop becomes ruined.

Now should a diseased tuber be used as "seed" in the following season, the fungus is ready to begin havoc all over again. This time it works from below upwards, and the roots, pushing into the growing potato-sprouts, gradually work their way to the leaves, where they again send out spore-producing branches, thus ensuring a continuation of the species in the following season.

Diseases of vegetables.—8. **Broad bean.**—Examine the growing tip regularly, keeping watch for the appearance of a small black aphis. Take a few insects and place them upon some matured leaves of the bean plant which are kept in water in the school-room. Allow a few to remain for a week or so on one, but only on one plant, in one of the garden-plots. Compare the rate of increase in each case.

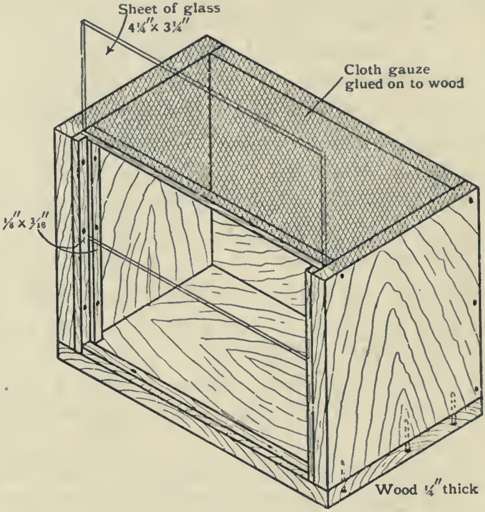

Fig. 88.—Breeding cage for insects.
Material—White wood or home-grown pine. Inside dimensions, 4¼″ × 3¼″ × 2½″.

The best preventive is to nip off the growing shoot immediately the flowers are well set, or any rate as soon as the aphis puts in appearance. This shoot should be burnt, or at the very least the aphis should be crushed, and the shoot removed from the garden-ground.

Broccoli, brussels sprouts, cabbages and cauliflowers.—9. **Cabbage butterflies.**—Search the backs of cabbage leaves in early summer for clusters of small whitish-yellow bodies which are usually to be found along the midribs. Destroy most of these, but take one leaf which bears these bodies and place it with the stalk immersed in a dish containing water in the school-room window. Examine each day. When small caterpillars emerge, remove them from the leaf and place them with fresh leaves, daily renewed, in a breeding cage.

At the same time examine the cabbages in the garden for caterpillars and place a few in another cage, feeding them regularly. When a chrysalis, or pupa, has been formed, put away the cages in a cupboard until early spring, when they should be placed again in the sunlight. Watch for any change. Examine the butterfly which emerges. Compare it with that which you now see flying about in the garden around the cabbages.

Have all the caterpillars formed chrysalids? If not, carefully examine those which have not thus changed. Do you note any small whitish bodies projecting from the caterpillar? Does this caterpillar develop into a butterfly? Keep these small white larvae also in a breeding cage until spring, and then expose the cage to the sun. Examine carefully the ichneumon fly which emerges. Are these friends or foes?

Cabbage butterflies.—There are three kinds of cabbage butterflies, but only two give trouble as a rule, *i.e.* the large white and the small white. The former is by far the more destructive. With regard to practical work in the garden, the student should make it his business to destroy as many of these as possible. For the eggs, these small whitish-yellow bodies already noticed, and also for the caterpillars, hand-picking is the only remedy which is of much avail. The large white lays its eggs on the backs of the cabbage leaves in clusters, usually along the midribs. The small white lays its eggs singly, and as a result those are more difficult to note, and individually give more trouble. Should any eggs be allowed to remain, the caterpillar appears usually in less than a fortnight from the time of laying.

10. **Ichneumon flies** develop from the eggs of a four-winged fly, which bores through the outer covering of the caterpillar, or of the chrysalis, and deposits an egg in the hole thus made. From these eggs the larvae develop, and these at once begin to feed upon the internal organs of the host. When fully grown they emerge, spin themselves golden-yellow cocoons in which they wrap themselves, and remain in this condition for a long time. In spring, as a rule, each changes, quickly passing through a brief period as a chrysalis from which the ichneumon fly emerges in a short time. The flies then proceed upon their work of destruction, preying upon the caterpillars and chrysalids

of the cabbage butterflies, and, therefore, should never be destroyed by the garden-worker.

11. **Cabbage root-fly** (Fig. 89).—In early summer, examine the cabbage plants daily, and should one show signs of wilting, dig it up carefully with a spade so as not to disturb the soil close to the roots. Lay plant and soil on a piece of board, and carefully and gradually remove the soil, keeping a look-out for foreign bodies. Can you note any short whitish maggot-like forms, either close to or protruding from the underground part of the stem? If so, place the plant in a small pot, apply plenty of water, and keep it in a window. Examine the soil once per week at least, keeping a look-out for small brownish bodies.

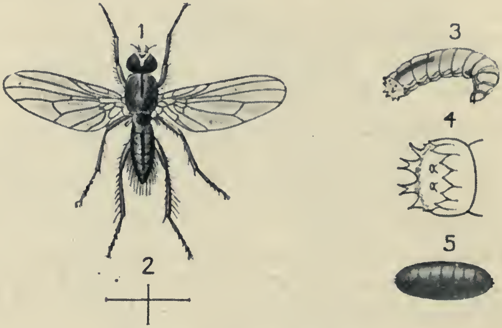

Fig. 89.—Cabbage root-fly.
1. Adult insect (magnified); 2. actual dimensions; 3. maggot (magnified); 4. last segment of maggot (enlarged); 5. pupa magnified.

This is the chrysalis, or pupa, stage of this fly. Place the pupae in a breeding cage set in a window. Examine the cage daily for signs of flies. Learn to identify these.

Place a few of the maggots in earth upon which a strong solution of common salt has been poured. Leave for 24 hours and examine. Do similarly using a solution of Epsom salts and of sheep-dip. Do any of these seem to have the power of killing off the pest? Pour some of each on to the roots of three healthy cabbage plants. Does any of the three seem to prevent normal growth?

The cabbage root-fly is a much more serious enemy than are the cabbage butterflies, and it often defies all attempts made at its extermination. It lays its eggs close to the stem of the plant, just under the surface of the soil, and from these in a very short period, often less than a fortnight, come short white larvae which attack the portion of the stem which is underground. The result is that the passage of moisture and food-material is obstructed, and as transpiration from the leaves proceeds at a greater pace than that at which it is supplied by the roots, the leaves wilt and droop. Earthing-up, as already noted, accompanied by copious supplies of water, may result in the growth of adventitious roots higher up than the affected part (Fig. 55), and an early variety may thus be brought to maturity.

12. Prevention of cabbage root-fly.—It is asserted that a solution of sheep-dip applied to the roots is a remedy, but perhaps the safest method to adopt is prevention rather than cure. This can be effected by fixing round the stem in early spring, during transplanting operations, a circular tarred disc which may be made easily from brown paper. A hole is punched in the centre to take the stem, and a straight slit made from the hole to the outside of the disc, thus allowing the stem to be set in position. The disc may be from 3 to 6 inches in diameter, and when set in position should be drawn tightly close around the stem, the flaps being overlapped in the process. Press this disc close to the ground.

The result is that the fly cannot get close to the stem to lay its eggs, which are therefore deposited so far away, that when the maggots are hatched they are unable, being legless, to travel through the soil sufficiently far to allow them to attack the plant.

13. Gall weevil.—Examine the roots of all plants of the cabbage family at the time of transplanting. Can you see any small rounded growths? If so, cut them off with a sharp knife and burn them. Retain one plant. Set it in a pot, supply it regularly with water, and keep it in the school-room where it will be under regular observation. Examine the soil carefully at intervals for pupae, and when you find one try to discover whence it has come. Examine the galls. Cut one or two open and find the whitish maggot inside. Place the larvae in damp soil in a breeding cage and watch development. Examine the beetles which appear, so as to know them by sight.

Burn all cabbage stalks when the head has been cut. This precaution and the careful cutting off of all abnormal growths at planting time should render the ground fairly clear of the pest.

14. Club root or finger-and-toe (Fig. 54).—Examine all plants at transplanting time, and burn those showing any signs of abnormal swellings of the root Retain one plant, set it in a pot, and treat as already advised (Exp. 13). After a time take up the plant, note the condition of the root, cut this open, note the nature of the contents, and if possible place a drop under a microscope. Describe what you see. Take a drop or two of this brown substance, and place it upon the root of a healthy plant also grown in a pot. Watch development and note.

Club root, or finger-and-toe.—This is caused by a fungus which attacks all members of the cabbage family, turnips and radishes being subject to the disease as well as the cabbage. As a rule, it is found that the disease originates in the seed-bed, and thus the garden-worker has a means at hand to prevent its entry into the garden, unless it has found a footing there already. By careful examination and burning of infected plants the garden may be kept clear of the fungus. If it already has a hold, quick-lime at the rate of a quarter of a pound to the square yard should be dug into the soil, and no acid manures should be used. In addition the roots of young cabbages should be washed thoroughly in a mud-bath of lime, soot, and sulphur, and allowed to dry somewhat before being planted.

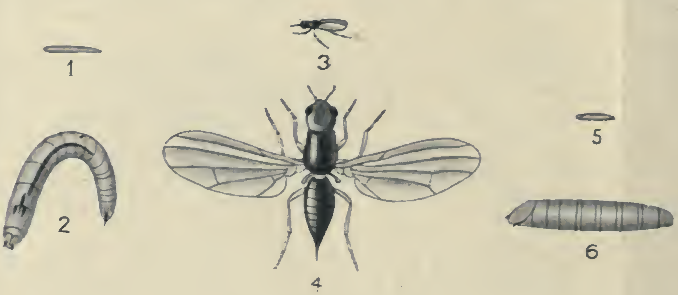

FIG. 90.—Carrot-fly.

1 and 2. Larva, natural size and magnified; 3 and 4. fly, natural size and magnified; 5 and 6. pupa, natural size and magnified.

Carrots.—15. Carrot-fly (Fig. 90).—Examine the carrot crop for any plants whose leaves are becoming pale in colour and are drooping. Dig up such carrots carefully. Examine for the presence of yellowish bodies about a quarter of an inch long. Replant one of the carrots in a pot, water, and after a fortnight empty out the soil and look for small pupae of a light-brown colour. If these are not to be seen, replace the soil and carrot, and examine daily until they appear. Place some of them with a quantity of soil in a breeding cage, and watch daily for the appearance of a small dark fly with a shiny body, reddish head, and iridescent wings. Examine it well so as to know it, and then destroy it.

The worst enemy the carrot crop has is the carrot-fly. Reference to it has already been made, its method of attack described, and remedies have been suggested (p. 123).

Onions.—16. **Onion-fly** (Fig. 91).—From the first week in May keep a lookout for any signs of yellowing and drooping of the leaves of spring-sown onions. When this has been noticed dig up the plant carefully, examine for maggots, and breed them in a cage by supplying them with pieces of onion for food. Place a little soil in the cage. Do the maggots move from plant to plant in search of food? Note the brown colour of the pupae, and examine the fly when it appears so that you may know it. When it does appear, introduce a growing onion plant into the cage, and later examine the leaves for eggs.

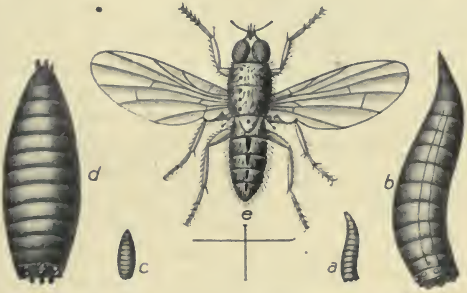

Fig. 91.—Onion-fly.

a and *b*. Larva, natural size and magnified; *c* and *d*. pupa, natural size and magnified; *e*. fly, magnified; lines showing wing expanse and length of body.

The first signs of onion-fly appear usually about the middle of May, when the first leaves of certain onion plants turn yellow and later become bleached in colour. Examination reveals a number of whitish maggots eating upon the bulb, which remains small and malformed. The maggot comes from an egg which is laid by a black-bristled, dark-grey fly, less than half an inch in spread of wings. The eggs are laid usually about the base of the leaves, and this gives an indication of the best method of preventing attack.

The plant is made distasteful to the fly if paraffin emulsion be applied just when the seedlings appear above ground, and twice or so afterwards at intervals of a week. Should disease appear despite this precaution, the plants should be dusted well with lime and soot mixed in the proportion of two of the former to one of the latter. This will adhere partly to the leaves if they are damp, but it is of use against maggots already formed only when it is well hoed into the surface-soil around the plants.

Potatoes.—**17. Potato disease** (Figs. 86 and 87).—The life-history of this fungus has already been described (p. 267). Attempt to distinguish between this disease and that known as leaf-curl.

No good can be done by pulling off decayed leaves and stems. The only remedy found to be effective when this disease has established itself in a district is the application of one or other of the preparations of copper known as **Bordeaux mixtures**, for which see page 290. It must be applied in a very thin spray, care being taken to drench the under side of the leaves as well as the upper. The garden-worker should not wait for the appearance of signs of the disease, but if the potato crop in the district has suffered in previous years, he should apply Bordeaux mixture in the last week of June, or early in July, according to locality. A second treatment should be given about three weeks later, and should the disease persist, a third may be necessary. The advice is sometimes given that early potatoes, as they mature early, need not be treated, but in the school garden where the earlies are grown alongside later varieties, this advice should not be followed.

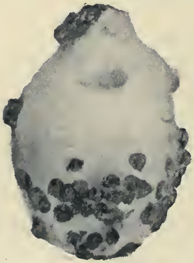

Fig. 92.—Brown scab on potato tuber.

So much for remedies. With regard to prevention, much lies in the hands of the garden-worker. Should "seed" potatoes be obtained from another district, each should be examined for signs of disease at the time of planting, and should even one spot be noticed, the tuber should be burnt. When the crop has been dug, all stems and diseased tubers must also be burnt if the garden is to be kept free from the disease.

18. Scab (Fig. 92).—Examine "seed" potatoes at the time of planting for any rough brownish patches or irregularly-shaped small wartlike growths of a blackish colour. Powdered sulphur should be rubbed on the growths, especially into the eyes of those with black scab, and in addition a handful of sulphur placed in the hole in which the tuber is planted.

Two different kinds of scab affect potatoes. That which is brownish in colour merely affects the outer skin of the tuber and in no way impairs the eating quality of the crop. Black scab on the other hand is more harmful, as it attacks the young sprouting stems and thus checks growth. In the former case the sprinkling of sulphur in the ground where the "seed" are to be planted should be sufficient, but in the case of black scab, which obtains its strongest hold upon the "eyes," sulphur must be applied both to the affected tuber and to the soil in which it is to be planted.

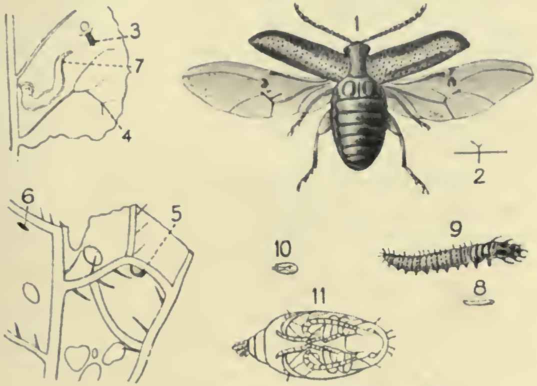

Fig. 93.—1. The turnip-flea-beetle. (Much magnified.)

2. Natural length and wing expanse; 3. natural size; 4 and 5. egg, natural size and magnified; 6 and 7. mine, and cuticle eaten away by larva; 8 and 9. larva, natural size and magnified; 10 and 11. pupa, natural size and magnified.

To be wholly rid of either of these diseases, precautionary methods are necessary. Lime furthers the growth of the fungus, as does also the application of farmyard manure. Indeed the fungus is often introduced to a garden by means of the latter when manure has been obtained from a farm where diseased tubers have been used as food for animals without first being boiled. When either of these diseases is noticed, acid manures alone should be applied to the soil for two years at any rate.

Turnips.—**19. Club-root, or finger-and-toe.**—This disease is the same as was found to attack cabbages, and, in fact, is often introduced to the garden by young diseased cabbage plants received from the nursery. When a turnip is found to be diseased, the best thing to do is to remove the plant and the soil around it, burn the lot, and lime the ground.

20. **Turnip-flea-beetle** (Fig. 93).—No difficulty will be found in obtaining a few of these beetles and working out their life-history and method of working by keeping them along with fresh turnip leaves in a breeding cage.

Reference to this pest has been made already, and precautions and remedies have been suggested (p. 134).

Diseases of fruit-trees and bushes.—21. **Fruit-trees.**—Examine the leaves and bark of your fruit-trees towards the end of April. Pick off all caterpillars, beetles, and weevils you can find. Save a few of each kind, which should be fed on fresh leaves or pieces of branches in a breeding cage. It is not sufficient to examine only the upper surface of the leaves. Many pests will be found on the under surface. Previous to beginning your search, shake each branch well, destroying all caterpillars, etc., which fall. Note the brown colour of those caterpillars found on the bark, and the leaf-green colour of the leaf-feeding ones. Carefully watch the changes which occur in the breeding cage, and attempt to identify each moth, etc., when it has emerged from the chrysalis form.

For the type of trees usually grown in the school garden, the best method of exterminating most of these pests is hand-picking. As a result of two pickings at an interval of a week, eighteen boys destroyed altogether 297 caterpillars found on eight trees at the Gordon Schools. This work occupied about twenty minutes on each occasion, and results were certainly definite.

Should hand-picking be thought an insufficient remedy, thoroughly wash the stems and branches about the middle of February with a burning substance known as Caustic Alkali Wash, for the constituents of which see page 290. This is especially useful for destroying all moss and lichens which grow upon the bark of the trees as they become older, and also for removing partly loosened pieces of old bark. In these hiding-places eggs may have been, or may be, laid where they are well protected during winter. This wash has been found to destroy the eggs of quite a number of these pests, as well as those of the red spider and certain of the scale insects themselves as well. It has, however, no effect upon the eggs of the winter moth. Those must be dealt with by hand-picking the caterpillars.

22. Apple canker (Fig. 94).—Towards the end of summer examine apple, pear, and plum trees for rugged patches on the bark. In crevices of these look for patches of a white substance. Examine a little of this by means of a pocket lens or under the low power of a microscope. Can you distinguish any signs of "seed," or spores rather similar to those found in the case of the fungus which causes potato disease? Examine again in spring. What is the colour of the spores now?

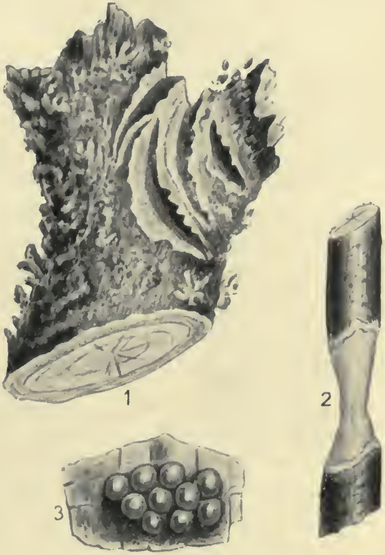

Fig. 94.—Apple canker.

1. Typical signs of attack; 2. young branch completely "ringed" by the fungus; 3. cases containing winter spores.

Note the type of bark possessed by the attacked tree or trees. What is the effect upon the leaf and fruit growth on the branch affected?

Apple canker.—The attack of this fungus is evidenced by the gradual eating away and decay of the bark round the affected part. Usually this is accompanied by a rugged thickening of the bark around the edges of the wound. From the first point of attack, the fungus works outwards. Often but one side of the branch is affected, the result being decreased vitality in the portion of the branch above. From his study of the growing plant the student should be able to account for this shortness of leaf and fruit development. In time, however, the fungus may extend its field of operations until it works quite round the stem (Fig. 94, 2). What will be the result of this?

This plant has no power to pierce the tissues of the unbroken bark of a fruit-tree; but given the presence of a wound, access is easily obtained. This wound may be caused by different agencies —by insects, by frost or hail in very young shoots, by pruning performed carelessly with irregular, ragged cuts, etc. Into the wood thus opened up, the spores of the fungus may be blown by wind, and finding a suitable environment the plant at once begins to grow. Its method of feeding is essentially similar to that of the fungus which causes potato disease, eating away and breaking up the tissues of the bark, so that the wood is exposed, with results as above.

Precautions against canker take the form of regular examination of the bark of the trees for wounds of any kind. Such wounds when found should have their edges cut away with a knife and then scraped, the removed parts being burnt. Gas tar should be thickly applied so as to form a coat. Should the attacked branch be young and thin, it should be cut back to a point below the affected part and the removed part burnt. If the branch be old, the loss of it would spoil the shape of the tree, so all that can be done is to scrape and tar the surface as above advised. If the fungus is noticed in late summer in the white stage, it can be killed by washing it thoroughly with a solution made by dissolving one pound of sulphate of iron in one gallon of water.

Black-currants.—23. Black-currant mite or "big-bud" (Fig. 95).—In spring examine your black-currant bushes for any appearance of unnaturally swollen buds, somewhat similar to those shown in Fig. 95. Remove a portion of the interior of one bud, and examine it under the low power of a microscope, or by means of a pocket lens. Describe what you see. Examine the buds also with a lens for any appearance of egg-like bodies.

Thoroughly prune back the branches of the affected bush, removing them from the garden with as little shaking as possible, and burn them. Take one twig showing signs of attack and one healthy growing shoot. Place them in water in separate dishes, keep them well apart, and note development.

The black-currant mite is by far the most destructive enemy of this plant, and during recent years so much harm has been done by it that in whole districts the black-currant crop has failed. And not for one year only is this true, for when a garden is once attacked it has been found almost impossible to rid the bushes of the pest. Hard pruning in some cases is beneficial when the removed shoots have been burnt and the growth of young wood is encouraged, while sprinkling with a powder, two parts sulphur to one part quicklime, in spring is sometimes of effect; but if these plans be of no avail, the best means the grower can adopt is to remove the surface-soil to the depth of two or three inches from around each bush and subject it to burning; then to dig up all affected bushes, burn the lot, and buy a fresh supply of bushes. This may seem to some an unnecessarily drastic method to adopt, but experience has shown that it is the most economical in the long run. Remedies have over and over again been advised, but none have as yet been found which are of much avail.

When new bushes are received they should be examined carefully, and any which show signs of "big-bud" should be burnt at once.

When the diseased and the healthy sprigs are developed indoors in water as advised above, it will be found that the affected branch produces neither leaves nor flowers, and could therefore bear no fruit.

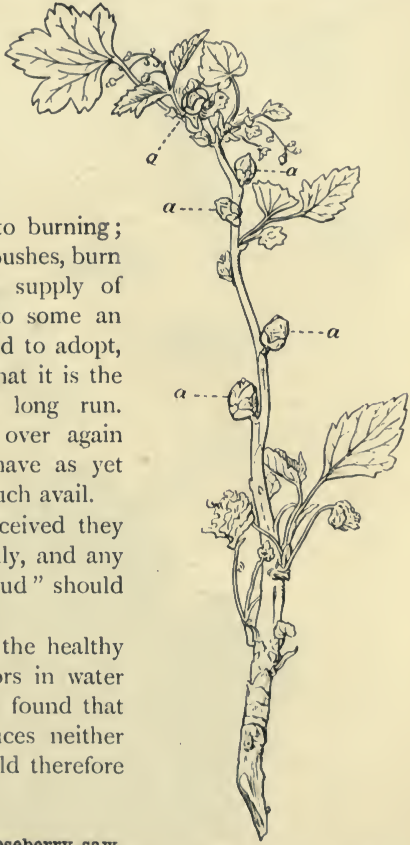

FIG. 95.—"Big bud" on black-currant spray.

a. Result of "mite" attack.

Gooseberries.—24. The gooseberry saw-fly (Fig. 96).—Search the backs of the leaves of gooseberry bushes in late April or May for greenish-white eggs which you may find close to the ribs of the leaves (Fig. 97). Destroy as many as possible of these, but place one or two leaves with eggs on them in a breeding cage. Examine carefully, and note how long the larvae take to emerge. Note their size and their method of attack upon the leaves. Supply fresh leaves daily, and note changes in colour which take place in the caterpillars. When cocoons are formed, watch for the appearance of the saw-fly, which should emerge in about three weeks. Examine the fly so that you may know the enemy. Introduce new leaves, watch for new eggs, feed the larvae from these when they hatch, and continue operations to find out how many generations can be produced in one season.

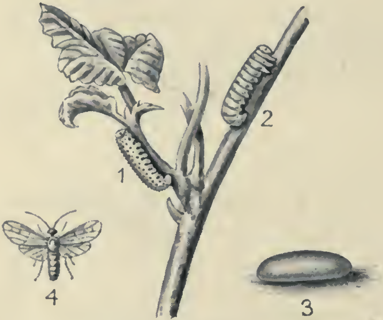

FIG. 96.—Gooseberry saw-fly.
1 and 2. Larva in the two last stages; 3. the cocoon; 4. the fly.

Hand-picking of the eggs of the saw-fly is not so difficult a matter as it sounds, and should a number be overlooked, leaves which have very young

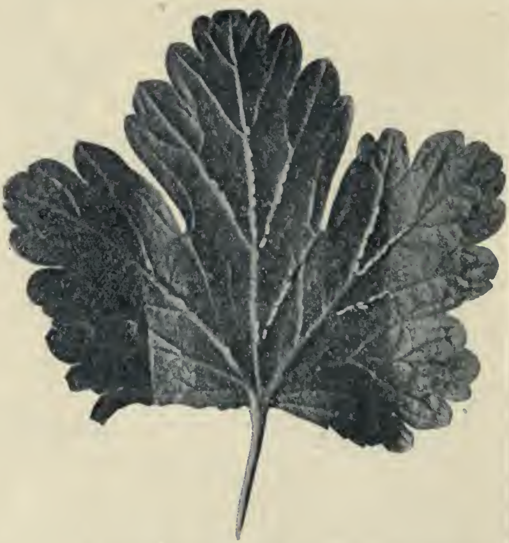

FIG. 97.—Eggs of gooseberry saw-fly on leaf, natural size. (Some 60 eggs were found on this leaf.)

caterpillars on them can be pulled and burnt without shaking off the larvae.

Should the attack be bad, a wash must be used, and for this purpose hellebore, or Paris green, is as effective as any. For the preparation of the wash see page 291.

Danger, however, still lies in the fact that caterpillars may have already dropped from the bushes, and having burrowed into the surface layers of the soil may have formed pupae there. To prevent these from maturing, either remove the surface four or five inches of soil and bury it in a trench down to the subsoil, or work into the surface layers a good sprinkling of quicklime in autumn.

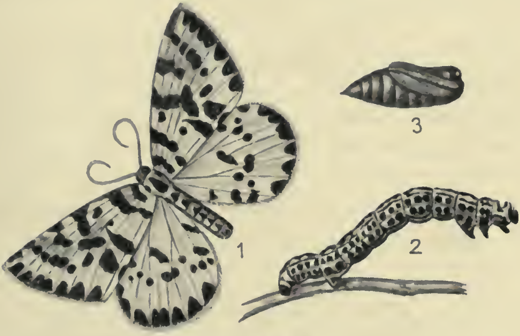

FIG. 98.—Magpie moth.
1. Moth; 2. caterpillar; 3. cocoon. All natural size.

25. Magpie moth (Fig. 98).—From the beginning of August onwards watch for the appearance of caterpillars upon the leaves, or of eggs of a yellowish colour with black dots, on the backs of the leaves beside the midrib. Place some of each or of either in a breeding box, feed the caterpillars regularly, and watch developments as in the case of the saw-fly. Note in what stage they pass the winter. Are these caterpillars or those of the saw-fly, therefore, likely to begin operations upon the bushes first in the following season? Note the black colour of the pupa stage later on.

The caterpillars of the magpie moth are often confused with those of the gooseberry saw-fly, but by working out the life-history as advised above the student will have no difficulty in noting the great differences which exist between the two, both in the caterpillar and in the perfect stages. He will also notice that the magpie moth passes the winter in the caterpillar stage, protected in chinks and crevices or enrolled in leaves, while the saw-fly, on the other hand, winters in the pupa stage.

Thus immediately the warmth of spring causes the young buds to burst, the caterpillars of the magpie moth emerge and begin their havoc. On the other hand, the saw-fly is somewhat later in making its appearance, and when it has emerged lays its eggs upon well-developed leaves. Thus its caterpillars are considerably later in beginning their attack, as they do not hatch from the eggs until about a week after these have been laid.

This at once suggests that all fallen leaves, weeds, etc., should be thoroughly raked from the soil in late autumn and burnt. Many caterpillars will thus be destroyed. In early spring, hand-picking should be resorted to. Should the attack persist, the plants must be sprayed thoroughly with Paris green in the first or second week in September. This should kill the young caterpillars soon after they make their appearance, at which time their skins are most delicate.

26. American gooseberry mildew (see frontispiece).—This disease was reported in this country for the first time in 1906, but since that time it has spread widely. In many districts so disastrous have been the effects that the growing of gooseberry bushes has been rendered impossible. Work out the life-history somewhat as follows : From April to November the first stage of the attack may appear. Soft leaves on young wood are usually the first to suffer, and as a result they curl upwards, and their under surface is seen to be covered with a white form of mildew, while the young shoots may droop at the points and the upper leaves hang downwards (see frontispiece). This is called the summer stage. Later a brown stage will be found, usually seen from June onwards, and called the winter stage. In winter the colour may change to a dirty grey.

During the white, or summer stage, the fungus produces its first set of spores, which, as has already been noted, may be compared to the seeds produced by ordinary garden crops. From these spores new plants develop later if placed under suitable conditions.

But given dry weather these spores fail to germinate and die, as they do not find the necessary amount of moisture.

The plant, however, gives rise to a second set of spores when it has reached the brown or winter stage, and should an affected twig be viewed with a pocket lens these spores will be noticed in the form of little black dots (see frontispiece). Each of these dark bodies contains more than one spore, in fact eight are usually found inside, and the whole is protected by a strong outer covering. This outer case protects the minute spores during winter time, until, with the advent of warm weather, the covering bursts and the young fungi make their way outwards.

Many of these winter-resting spores may be found on twigs during the winter months (see frontispiece), but by far the greater number fall off and lie in the surface earth, germinating in early summer. A number may appear in May, but the greater proportion remain dormant until the heat of the summer increases in June or July. In almost all cases soft young wood is found to be the first to be attacked, while those varieties of bushes which have a tendency to luxuriant growth are more apt to be affected than are those of more compact habit.

The first point of importance in the attempt to keep the garden free from gooseberry mildew is to take all possible precautions to see that the bushes are absolutely clean when received from the nursery. A guarantee that they are free from American gooseberry mildew should be demanded at the time of ordering. Even then the plants must be examined almost daily right through the months of June, July, August, and September following planting. There is no excuse in a school garden for permitting this fungus to get a strong hold before its presence is noted. Every garden-worker should know what to look for, and if one pupil looks over the few bushes each morning, bringing to the school-room any leaves of which he is suspicious, not even one day need be lost.

Precautions and remedies.—Remember in the first place that the spores of this plant are extremely minute and multitudinous in number. Therefore they may be carried easily from plant to plant, or from the school to the home garden on the boots, clothes, etc., of the garden-workers. Only one student, therefore, should treat affected bushes. Many workers working together are more likely to spread the fungus rather than to eradicate it. The other pupils should stand outside the fruit-plot, watch what is done, and discuss the advisability or inadvisability of each operation.

27. Treatment of the disease.—Obtain an iron pail containing some paraffin, break off all affected shoots, leaves, etc., place them in the pail, and burn them as soon as possible. Make up a spraying mixture of 1 lb. of liver of sulphur to 32 gallons of water into which 1½ lb. of soft soap has been dissolved, and thoroughly syringe the attacked bush and those in its vicinity, using the finest rose of the syringe. Then spray the whole of the gooseberry and currant bushes with the same mixture. Should the attack be noticed before the fruit has formed, Bordeaux mixture may be used for spraying with greater effect. Make up this mixture as advised on page 290, but in this case let the proportions be 2 lb. copper sulphate, 2 lb. freshly burned lime, and 20 gallons of water.

It may be thought that if all attacked parts be removed spraying is unnecessary, but it must be realised that thousands of spores may have been produced and liberated even before the twigs and leaves were broken off. In addition many may be shaken off in the very act of removing the affected parts, and therefore these still remain on the bushes or on the soil underneath. Some may even have been borne by the wind to other bushes, so that spraying of the whole bush-fruit plot is necessary.

The American gooseberry mildew Order of 1911 enacts that every person who has on his premises any gooseberry or currant bushes which have been or are affected with the American gooseberry mildew, or are suspected of being affected, is obliged to report the fact to the Board of Agriculture and Fisheries, or to the Local Authority for the district, or to one of the Inspectors of the Board or of the Local Authority. The penalty for neglect to report is £10.

Rose bushes.—Roses are subject to a very great number of pests, and the number of different kinds of insects that captured caterpillars develop into is surprising. Fortunately the method of dealing with most of these is similar, namely, pressing the closed-up leaf (Figs. 99 and 100) firmly between the finger and thumb and removing the leaf. Often a leaf will be found to be tenantless, and then an examination should be made of the adjacent leaves, especially young and tender ones, where the pest will usually be found. Should the season be warm and dry, it will be necessary to examine the bushes almost daily if the plants are to do their best. If this be done, and there is little reason why it should not, as ten boys will hand-pick as many bushes in five minutes, there should be no necessity for the application of any wash such as Paris green.

28. Rose mildew.—Should the young growing stems of your rose bushes show signs of drooping, and examination reveal the presence of a whitish mould upon the young bark and leaves, some of the mould should be examined under a microscope.

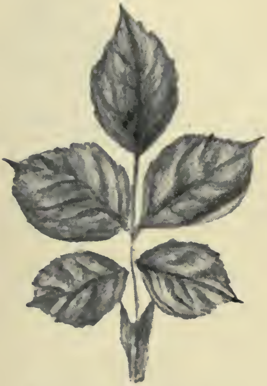

FIG. 99.—A healthy rose leaf.

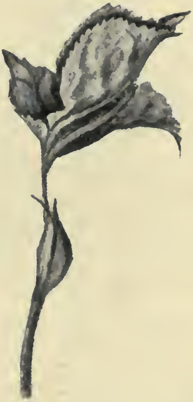

FIG. 100.—Rose leaf as a caterpillar's "home."

Very little examination will show that rose mildew is caused by a fungus, and as is the case with all such plants, it propagates itself by means of spores. As the spores are very minute they are carried about by every puff of wind, and thus the fungus may spread over all the rose bushes in the garden in quite a short time. The fungus, like the American gooseberry mildew, produces winter spores, thus ensuring the propagation of a new set of plants in the following year.

Several conditions may result in the development of this plant. Should roses be growing in close damp unventilated places they rarely escape, while cold winds and lack of moisture at the roots also result in such growth in the plants as causes them to fall an easy prey to the fungus. Should diseased leaves be allowed to fall upon the ground and be left there, the bushes are certain to suffer in the following year. Therefore all fallen leaves should be raked off and burnt in late autumn. This, however, is insufficient to prevent attack. As in the case of several other fungi, this plant succumbs to the application of flowers of sulphur. To this one-third of its quantity of slaked lime may be added with advantage. This mixture should be rubbed on the upper and under sides of the leaves, and should a shower of rain wash it off it must be renewed. If this be done carefully, the fungus should be stamped out.

Pests common to several plants.—Aphides or plant-lice.—Unfortunately there is little trouble in finding as many specimens of these as we please. Few cultivated plants are free from one form or another of aphis, whether green-fly, black-fly, dolphins, or smotherers be the name applied to them. To work out the life-history, however, but one full-grown specimen should be placed in a breeding box, and a type of life-history considerably different from any of those already described will be found.

No matter what variety is examined it will be found that the broad details of its life-history correspond to those of the life-histories of the others of this species. The adult is sometimes winged, sometimes wingless. The females produce living young, which in a very short time attain full growth and in turn produce living young insects. This multiplication is extremely rapid, and a shoot which has but one or two specimens when first examined may be covered with aphides in a few days. As the weather becomes colder the females deposit eggs which persist throughout the winter on leaves, stems, etc., and from which perfect forms are hatched in the following year. Some, however, spend the winter as insects.

Hot weather and insufficient moisture check the growth of plants, and at the same time present ideal conditions for the multiplication of aphides. The vitality of the plant is decreased by the arrest of growth, and so when it is attacked by plant-lice it is much less capable of resistance than when it is in a healthy condition.

Plant-lice are insects which are capable of piercing the outer skin of young bark and leaves, and are provided with a sucking mouth for extracting the sap of the plant. In the early stages they are usually found upon the under surface of the leaf, where their attack hinders the growth of the tissues on the under side compared with the rate of growth on the upper, thus causing the leaf to curl downwards (see Figs. 101 and 102). Naturally this loss of sap, combined with the already mentioned shortage of moisture, greatly impairs the vitality of the plant, and when in addition it is remembered that these insects excrete through two tubes visible on their backs a sticky substance called "honey-dew," which effectively closes up the stomata of the leaves, it will be realised how great a tax is laid upon the plant by an attack of this kind. Too often green fly is looked upon as a lesser evil, but it is evident from the above that such a view is incorrect, and the garden-worker who does not take means of destroying the pest is doing but little justice to his crops.

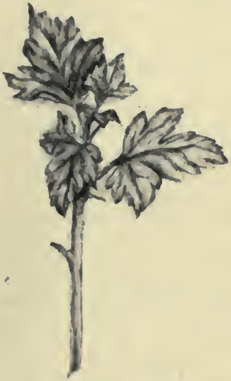

FIG. 101.—Healthy gooseberry spray.

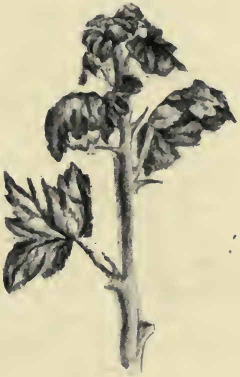

FIG. 102.—Gooseberry spray attacked by green fly. Note the downward curl of the leaves.

29. Destruction of aphides.—For roses which are attacked, as good a method as any is running the finger and thumb along the affected part of the stem, thus crushing hundreds in a few minutes. Dipping the parts in hot water (about 125° Fahr.) also kills the aphides and does no harm to the roses. Should a wash be desired, less than a quarter of a pound of strong, soft soap dissolved in two gallons of water is very effective. These insects breathe by means of pores which are placed on their bodies ; the soft soap closes these and death results.

Certain plant-lice, the woolly aphis for example, are immune to such an application. In this case paraffin emulsion must be used.

Insecticides and fungicides.—**30. Bordeaux mixture.**—Several recipes for this wash are in common use. The method given here is advised by the Board of Agriculture and Fisheries.

Sulphate of copper, -	3 lb.
Quicklime, - - -	1½ lb.
Water, - - - -	25 gallons.

Put 12½ gallons of water into a wooden or earthenware vessel (an old paraffin cask does very well), place the sulphate of copper in a piece of sacking and suspend it just beneath the surface of the water. Leave it there until it has dissolved wholly. On no account should a vessel with iron in its construction be used, for the copper sulphate will act upon the iron parts.

In another vessel place the quicklime and pour water on to it, adding a little at a time, until the whole is made up into a smooth thin paste like cream. Allow this to cool. Then pour it through a piece of coarse sacking into the solution of copper sulphate, stirring well the while. Add sufficient water to bring the whole up to 25 gallons. Stir well and use as soon as possible, stirring the mixture occasionally during the operation.

The danger with this mixture is that the whole of the copper sulphate may not be acted upon. To obviate the danger of the foliage being burnt, obtain a very little potassium sulphocyanide (one ounce costs threepence). When the mixture you have made has somewhat settled, take some of it in an earthenware dish, drop in a crystal of the sulphocyanide, and stir with a clean stick. If a deep chocolate colour is the result, copper sulphate which is still unacted upon is present in the mixture and the lime used has not been strong enough. More lime must therefore be added in paste form until the whole of the copper is acted upon.

31. Caustic alkali wash.—Dissolve ½ lb. of commercial caustic soda in water. In another dish dissolve ½ lb. of crude potash in water. Mix these together, stir well, and add ½ lb. of soft soap, pouring in water to make the whole up to 5 gallons. Stir this well, and apply with the fine rose of a syringe. Care must be taken that the wash does not fall on the hands or clothes of the worker, as it has a burning effect.

32. Hellebore.—Mix 1 ounce of hellebore powder with 3 gallons of water and add 2 ounces of flour. Stir well, and apply with the fine rose of a syringe. It is necessary to keep the mixture constantly stirred during application.

33. Paris green may be applied as a dry mixture or as a wash. For the former one part of Paris green to fifty parts of flour makes a good mixture, which may be dusted on to the leaves.

Paris green is practically insoluble in water, so that if applied as a wash the moisture must be kept well stirred. One ounce of the poison to 10 gallons of cold water is the proportion usually used, a little quicklime being added to the mixture. As the lime neutralises the small amount of free acid which the salt contains, the tendency to scorch the foliage is diminished.

34. Paraffin emulsion.—One pint paraffin, 2 quarts of water heated to boiling point, and about half a pound of soft soap well mixed by stirring, form the basis of this wash. Add about 2 quarts of cold water and again stir. If the wash be pumped through the syringe several times, the constituents can be mixed more thoroughly. Apply with a syringe.

35. Quassia.—Boil 4 ounces of quassia chips for about a quarter of an hour in 1 gallon of water, or infuse in the same quantity of cold water for 12 hours. Strain off the chips, add 4 ounces of soft soap, and stir the whole well. When the mixture cools add 1 gallon of cold water and apply with a syringe.

36. Sheep-dip is but a name given to a number of different preparations, several of which are useful for horticultural purposes. Proprietary mixtures are sold both in liquid and solid form, and these may be used, the strength of the solution necessary for the extermination of each different pest being found out by trial. Should the garden-worker prefer to make up a solution for himself, the following will be found effective:

Liquid carbolic acid, -	¾ lb.
Soft soap, - - -	½ lb.
Water, - - - -	10 gallons.

This forms an emulsion, *i.e.* the soft soap by combining with the oil and the water causes these two to unite, a process which would not have taken place had the soap been lacking. The soap should be dissolved well in a small quantity of hot water, the carbolic acid added, the mixture well stirred, and sufficient cold water added to make the whole up to 10 gallons.

CORRELATED EXERCISES.

1. What are the characteristics of a healthy growing plant?

2. What is implied by "a diseased plant"?

3. Distinguish between cause of disease and evidence of disease.

4. How would you judge from the general appearance of a plant that it is diseased?

5. What exactly is the cause of the wilting of the leaves of a cabbage, no matter what be the cause of the disease of which wilting is one of the symptoms?

6. Name as many insect pests as possible (1) which feed by biting the leaves of plants, (2) which are provided with a sucking mouth and suck the plant-sap from the leaves. Distinguish between the methods which must be employed in the extermination of each of these types.

7. Describe in detail the life-history of the fungus which causes potato disease.

8. From an examination of the changes which occur in the insects you place in breeding cages describe the life-history of the large white cabbage butterfly, *or* of a winter moth, *or* of the onion-fly, *or* of the carrot-fly.

9. Describe the life-history of a green-fly.

10. Examine a rose-shoot affected by mildew. Cut into the affected stem. Follow the path of the fungus upwards. Describe what you find. Which part of the bud is first attacked?

11. Account for the growth of mould upon damp bread exposed to the air.

12. Should a disease appear upon one of your plants concerning which you know nothing save the fact that it is caused by a fungus, describe what steps you would take to eradicate it—steps based upon what you have learned from this chapter. Should this method be unsuccessful, what would you then do?

13. On return to school in September it was found that most plants of the cabbage family were attacked by the "finger-and-toe" fungus. Describe what immediate steps you would take and how you would reduce the possibility of attack in the following year.

14. Layered carnations which have rooted and have been cut away from the parent plant begin to die off. Describe how you would examine the plants with a view of finding out the cause. Suppose you found that the plants are rotting off at the neck, what steps would you take?

15. One onion plant in a row shows signs of wilting. In such a case, what would you do?

16. Seedlings grown in a shallow box in a frame gradually all "damp off." It is necessary to make a second sowing. Describe how you would do so, and what precautions you would take to prevent a repetition of the attack.

CHAPTER XIV.

CALENDAR OF GARDEN WORK.

JANUARY.

General remarks.—This is a most unsatisfactory month for outdoor work in the school garden, but certain operations must be carried on now, or a loss of time will be experienced later. The making and mending of garden tools will occupy most of the time allotted to practical work, but many of the experiments with soils can be performed now indoors, while the examination of already taken weather observations should be carried on as regularly as the geography lesson (p. 41).

Practical work.—Vegetables, etc.

Dig over all the ground not already worked, with restrictions as to weather and condition of soil as already given (p. 51).

Barrow-on manure to the plots when the soil is frost-bound.

Make out your seed order and place it with seedsman at once (p. 48).

Make and mend garden tools and requisites.

Clear away all rubbish and decayed vegetable matter from the garden-ground.

Potatoes.—Set early tubers to sprout (p. 83).

Practical work.—Flowers.

Keep the beds clean from rubbish.

Practical work.—Fruit.

Prune and tie up trees as weather permits (pp. 241-251). Choose some of the cut shoots about 18 inches long for grafting purposes, label each by name, and insert them 3 or 4 inches deep in a corner of the garden. Spray fruit trees with caustic alkali wash.

FEBRUARY.

General remarks.—The weather is now more favourable, but no work must be attempted either in digging or sowing unless the soil is in a suitable condition. Continue experimental work. Walks should be attended to. Garden requisites should still be made.

Practical work.—Vegetables, etc.

Prepare garden frames (p. 87).

Watch for an opportunity of forming a mulch of dry soil on the surface by forking-over and thus conserve the soil-moisture (p. 52).

Celery.—Seeds should be sown in boxes and placed in a hot bed about the end of the month.

Leeks.—Sow in cold frame, or outside if weather be suitable.

Onions.—As an experiment, some seed may be sown in the open during the second fortnight.

Parsnips.—Drop seeds in clumps in the row as soon as the condition of the soil will permit (p. 77).

Peas.—Treat with paraffin or red lead to keep away mice, etc., and sow as soon as conditions of soil are favourable. Earth up to protect from frost as they appear above ground, and support in good time (p. 128).

Potatoes.—Look over the sprouting tubers, and remove any which may show signs of unhealthiness.

Rhubarb.—If a new bed is desired, lift the old stools, divide, and replant the best crowns, giving a generous supply of manure and covering with long litter.

Cover established clumps with boxes, etc., and surround a few with long litter.

Shallots.—Plant as soon as the ground is fit (p. 79).

Practical work.—Flowers.

About the middle of the month sow sweet-peas out-of-doors.

Rather than have a whole season lost, plant out any border plants and roses which are not already in their place, but only when the soil is in good condition.

Treat flower borders with a mixture of leaf-mould, well-rotted manure, etc., working it into the soil by means of a rake.

Sow seeds of half-hardy annuals in slight heat.

Sow seeds of hardy perennials in a cold frame.

Practical work.—Fruit.

Finish pruning, etc. Spray thoroughly (p. 278). Any young trees and bushes not yet planted out should be set in their places before the end of the month (pp. 229-232).

MARCH.

General remarks.—This month marks the beginning of steady activity on the part of the garden-worker, and each week will bring duties which Friday must see completed or results will be most unsatisfactory.

Procrastination is the begetter of weeds, late crops, and a hundred other children of mismanagement with which the true gardener is ashamed to own even acquaintance, and the only method of keeping them away from the garden is doing things at the right time.

Practical work.—Vegetables, etc.

Broad beans.—Sow in the early part of the month (p. 74).

Beet.—Half a row of the globe-shaped variety per plot should be sown in the last week (p. 74). Protect the seedlings from frost and birds.

Broccoli and late cauliflower.—Should be sown late in the month, and if these, or the cabbage plants, do not seem to be making growth after they appear above ground, a very slight dressing of nitrate of soda, merely a pinch to the square foot, should be applied mixed with sand. Keep down any weeds.

Brussels sprouts and cabbage.—Sow seeds of a late variety in the early part of the month.

Celery.—Prick off the young plants into boxes giving plenty of room.

Early cauliflower.—Plant out from cold frame as soon as possible.

Herbs.—Examine those established, clean, divide if necessary, and apply rotted manure as a mulch.

Leeks.—Prick out the young plants in boxes.

Lettuce.—Sow seeds in cold frame.

Onions sown in the cold frame in September are now ready for planting out.

Parsnips.—Protect February-sown seedlings if necessary.

Peas.—Earth up the row and insert stakes at once (p. 128).

Potatoes.—A few sprouted tubers may be planted in the experimental plot this month, but it is better to delay planting for the general early crop until early April.

Winter greens (curly kale).—Sow seeds now thinly.

Practical work.—Flowers.

Prune roses, hybrid teas, and hybrid perpetuals towards the end of the month and teas in the beginning of April (p. 157). Select cuttings from the prunings and set them to root (p. 165). Slightly fork over the trodden-on rose bed and lightly cover with matured farmyard manure, if such a mulch is believed in.

Sow seeds of annuals thinly (p. 89).

Plant out carnations which were layered in July and August. Sow seeds of carnation in boxes in slight heat, and shade each box slightly until the seeds germinate.

Sow sweet-peas for a later show.

Plant out lily bulbs, if this has not been done in late autumn. Once planted they should not be moved. Carpeting the soil above them with sedum, saxifrage, white thyme, etc., results in protection to the lilies and gives bloom before they are open.

Half-hardy annuals might be tried outside at the very close of the month.

Attend to rockery, reducing carpeting plants where necessary and applying leaf mould.

Clip box edgings.

Propagate geraniums, begonias, etc., from cuttings (p. 167).

Practical work.—Fruit.

Examine trees and bushes regularly for pests which should be hand-picked.

Begin now to work out the life-history of as many as possible garden pests (pp. 226-290).

APRIL.

General remarks.—The garden will now need all the time that can be given to it, and usually that will be barely enough. The work for each week should be planned, and no alteration made, save what may be occasioned by the weather or the condition of the soil.

Practical work.—Vegetables, etc.

Broad beans.—Allow but one stem to come on each plant (p. 119).

Beet.—If the weather has been unsuitable for the sowing of globe-shaped beet during the end of last month, they should be dropped in now. If flavour is what is aimed at more than size, the larger seedlings should be pulled out at thinning time and the smaller left.

Brussels sprouts.—Thin out from seed-bed, and transplant into vacant ground 6 inches apart each way.

Cabbages.—Those planted in September should be hoed regularly, and receive slight applications of nitrate of soda at intervals if the weather be very cold. Seedlings should be treated in the same way as advised for Brussels sprouts.

Carrots.—Sow now. Thin out soon after the seedlings appear above ground. Apply sheep-dip immediately they appear and once a week after thinning; also pack the surface soil hard about the plants (p. 75).

Cauliflowers.—Protect from cold winds and night-frosts.

Celery.—Make sure the plantlets make steady progress (p. 124). Dust occasionally with soot.

Leeks.—Plant in their permanent position after they have been well hardened off. Give plenty of water.

Lettuce.—In showery weather plant out from frame. Water well.

Onions.—See that the plants receive no check in growth (p. 126). Sow seeds of a pickling variety on firm ground, and do not thin out.

Parsley.—Sow seeds in the early part of the month. Thin out later to 4 or 6 inches.

Parsnips.—Thin out to 3 or 4 inches, and later to 6 or 8 inches.

Peas.—Earth up and stake well. If plants come up too thickly, thin out. Set traps for slugs, and protect against birds (p. 128).

Potatoes.—Plant out early sprouted varieties (p. 130). Collect a supply of material for protection against frost. Bracken is as good as any. The later varieties may be planted during the last fortnight, or in May as desired.

Salsify.—Sow seeds in rows. Thin out first to 4 inches and then to 8 inches.

Spinach.—Sow seeds in rows about the beginning of the month.

Turnips.—Early Milan seeds should be sown about the middle of the month, golden ball a little later. Dust the seedlings with soot.

Practical work.—Flowers.

Plant out pansies, pentstemons, violas, etc. Apply some superphosphate to herbaceous plants, bulbs, etc.

Practical work.—Fruit.

Protect gooseberries from birds, and keep a sharp look out for pests.

MAY.

General remarks.—During this month difficulties will arise in maintaining continuous growth in all crops owing to increased evaporation of soil-moisture as the heating effect of the sun grows stronger. Thorough watering may be necessary in some cases, and throughout the garden a surface soil-mulch should be maintained. Twice per week at least the whole plot should be gone over, and conditions made as suitable as possible for steady growth.

Practical work.—Vegetables.

Broad beans.—Give liquid manure as needed. Support. Pinch out the growing point when the required height has been reached (p. 119).

French beans.—Sow seeds well apart in the beginning of the month.

Runner beans.—Sow thinly in the later part of the month.

Beet.—Thin out the globe varieties and sow long beet, giving the plantlets protection from birds.

Broccoli.—Set out March-sown plants now. Examine these and all those of the cabbage family for signs of gall weevil on the roots (p. 273).

Brussels sprouts.—Plant out and water well.

Cabbage.—Set out March-sown seedlings. Water copiously.

Carrots.—Thin out. Make the soil firm around the plants and apply sheep-dip (p. 123).

Cauliflowers.—Set out as the plants become large enough, treating as for cabbages. Liquid manure is necessary.

Celery.—Prepare trenches (p. 76). Prick out when large enough, and dust with a mixture of wood ashes and soot. Water regularly.

Lettuce.—Supply them with plenty of water, and with liquid manure occasionally.

Onions.—If spring sowing has been practised, the plants are now ready for thinning-out. Keep a look out for fly attack (p. 275).

Parsnips.—Continue thinning-out as required, and loosen the surface soil.

Peas.—Supply with liquid manure, and make sure the staking is sufficiently strong and high (p. 128).

Potatoes.—The planting of main crop and late varieties may be put off till now, according to the time at which harvest is desired. The first week of the month is usually late enough. Earth up well those appearing above ground (p. 130).

Spinach.—Thin out as required.

Turnips.—Sow seeds about the middle of the month. Thin out the plants of the early Milan variety. Safeguard from the flea-beetle by dustings of soot and wood ash. The application of a little nitrate of soda helps to rush the plants beyond the seedling stage and thus to escape the beetle.

Practical work.—Flowers.

Thin out annuals.

Sow biennials in the open in the last week.

Practical work.—Fruit.

Examine closely for insect attacks, and apply sprays as needed (p. 290).

Maintain a good dust-mulch between all trees and bushes.

JUNE.

General remarks.—Each week will bring work which must be done if good crops are to be obtained. As during May, much attention should be given to maintaining the necessary amount of soil-moisture, while the progress of each crop should be watched carefully, and the correct time for thinning-out seized upon. A soil-mulch must be maintained steadily.

Practical work.—Vegetables, etc.

Broad beans.—Supply with liquid manure once per week, but never when the soil is very dry (p. 117). Keep a sharp look out for the black aphis (p. 270).

Kidney beans.—Thin out well. Support if necessary.

Runner beans.—Thin out, two to a pole. Mulch with manure and keep the plants sufficiently moist at the roots.

Broccoli.—Firm the soil around the roots. Maintain a dust-mulch (p. 112).

Cabbage.—Keep the hoe going, earth up, and water once per week with liquid manure. Apply a solution of sheep-dip or Epsom salts should the cabbage root-fly make its presence evident (p. 272).

Cauliflower.—Treat as for cabbage. Tie one or two of the leaves over the head to preserve the colour. Plant out March-sown plants.

Carrots.—Water between the rows with a solution of sheep-dip.

Celery.—Dust when damp with wood ashes and soot. Cut away all suckers.

Onions.—Dust with soot in damp weather. Water occasionally with liquid manure.

Lettuce are now ready for use.

Peas.—Apply liquid manure once per week. Pull the pods as soon as they become full enough, never allowing a pod to ripen. Pick out the growing points (p. 130).

Potatoes.—Continue earthing-up as needed. Apply Bordeaux mixture about the third week (p. 276).

Radishes are ready for use.

Shallots.—Loosen soil from around the bulbs (p. 133).

Turnips.—Begin to pull now from the early Milan row.

Practical work.—Flowers.

Plant out half-hardy annuals.

Stake and support all plants needing it.

Take cuttings of pinks, etc.

Practical work.—Fruit.

Place straw under strawberry plants and net them.

Spray or hand-pick trees and bushes as required.

Thin out apples and pears.

Raspberries like copious supplies of water and liquid manure once per week.

JULY.

General remarks.—Water must be applied regularly where it is required, the soil mulch should be renewed at intervals, and all decayed leaves, etc., removed from the plots. Not even for one week can the crops be left to take care of themselves if the best results are to be obtained.

Practical work.—Vegetables, etc.

Beans (runner).—Supply with water and liquid manure.

Beet.—Maintain a dust-mulch.

Cabbage.—Continue earthing-up. Apply sheep-dip or Epsom salts solution if needed. Sow spring cabbages about the second week.

Carrots.—Apply a solution of sheep-dip if necessary, but the plant should now be beyond danger of attack.

Cauliflowers.—Water with liquid manure once per week.

Celery.—Apply liquid manure. Continue to dust with soot and wood ashes.

Leeks.—Plant out as soon as the broad leaf is well developed (p. 125).

Peas.—Water well, and occasionally apply liquid manure.

Potatoes.—Continue the application of Bordeaux mixture. Earth up finally as the plants will soon be too large to work among. Lift early varieties as they become ready for use (p. 130).

Shallots.—Loosen the roots, allow the bulbs to remain in position for a few days, and spread out in a sunny position to dry (p. 126).

Spinach.—May be sown about the third week for winter use. Thin out well.

Practical work.—Flowers.

Remove all faded flowers and leaves, and permit no plant to seed unless specially desired.

Propagate carnations by layering (p. 169).

Separate out biennials and perennial seedlings to encourage sturdy growth.

Bud roses (p. 173).

Practical work.—Fruit.

Summer-prune where shoots are not required (p. 242).

Harvest strawberries, etc., as they become ripe.

Still keep a sharp look out for pests.

Thin late apples and pears.

AUGUST.

General remarks.—If crops have been well treated up to this point, they require but little attention during this month, except that they must be harvested at just the right time. Weeds will now begin to give more trouble than formerly, but if a soil-mulch is maintained they will not be able to make much progress.

Practical work.—Vegetables, etc.

Beans (runner).—Need constant waterings. Harvest the pods as they become large enough.

Broccoli.—Plant out in permanent quarters (p. 75). They can well take the place of shallots which have been harvested.

Cabbage.—Sow seeds for spring use, scattering them thinly on the bed and thinning-out well later on.

Cauliflower.—Tie leaves over the heads (p. 124). Supply plentifully with water and liquid manure and examine carefully for caterpillars, which may be destroyed, if a dainty method be desired, by dropping them into a strong solution of salt.

Celery.—These need careful attention with water, liquid manure, and frequent dusting. Begin earthing-up.

Lettuce.—A sowing should be tried now to stand during winter. Thin out well.

Onions.—Now ripen off. Sow seeds in a cold frame early in the month for planting out in March. Sow seeds outside about the first week (p. 77).

Parsley.—Make a sowing now for winter use, sowing thinly, and later thin out well (p. 77).

Peas.—Supply with heavy soakings of water and liquid manure, and dust with sulphur should mildew make an appearance.

Potatoes.—Apply Bordeaux mixture if required. Harvest as they become ripe.

Spinach.—A further sowing may be made in case of failure of those sown last month.

Practical work.—Flowers.

Layer carnations (p. 169). Fill up blank spaces where plants have ceased blooming.

Practical work.—Fruit.

Gather fruit as it ripens. Cut young strawberry plantlets free from the parent, and after a few days plant them closely in a line in an empty space (p. 165). Plant out in a bed in March.

SEPTEMBER.

General remarks.—Harvesting must be done just when each crop is at its best, for if allowed to remain past this point in their growth their value is much reduced. This necessitates the careful examination of each crop grown. Weeds will continue to give trouble, especially in the herbaceous border, where it is impossible to work with a Dutch hoe.

Practical work.—Vegetables, etc.

Beans (runner).—Need heavy soakings of water and liquid manure. Pods should be gathered closely (p. 120).

Beet.—Harvest before frost has a chance to touch the roots. Use a fork in the process, and avoid any injury so as to prevent bleeding (p. 120).

Cabbages.—Seeds already sown may have made too much progress and be too soft to stand the winter ; so, seeing the expense is so small, an additional sowing should be made now, with precautions as already given.

Cauliflowers.—Sow seeds in a cold frame in the first week.

Celery.—Continue earthing-up, and supply with water and liquid manure.

Leeks.—Earth up to ensure blanching.

Lettuce.—Plant out August-sown seedlings in a sheltered position.

Onions.—Ripen off carefully (p. 126). Lay out to the sun in a dry place and turn over each day. Store by roping or otherwise.

Peas and beans.—Remove all haulms of useless plants. Store stakes, from which all pieces of haulm must first be removed.

Potatoes.—Harvest as they ripen and store in a pit if necessary.

Practical work.—Flowers.

Propagate by cuttings such tender plants as geraniums, verbena. heliotropes, etc. (p. 167).

Practical work.—Fruit.

Plant out strawberries.

Break off growth on fruit trees which has come since summer-pruning (p. 242).

Cut away old raspberry canes (p. 253).

OCTOBER.

General remarks.—Harvesting will continue to demand attention, and all refuse should be removed from the plots as the crop is pulled. This is the month in which rough digging of the soil for winter begins, and this operation should not be delayed, every suitable day must see a certain amount of digging done (p. 23). Care must be taken that no parts of plants showing signs of disease are dug into the soil during this operation. Leaves and turf should now be collected.

Practical work.—Vegetables, etc.

Cabbages.—Draw earth to the stems of those for spring use.

Carrots.—Lift without injury to roots and cut off tops close to the crown. Store in sand or in pits.

Cauliflowers.—Beware of allowing the plants to shoot, and remove all stumps from the soil.

Leeks.—Stand frost hardily. Earth up well.

Parsnips.—Cover with a good layer of fallen leaves. They are quite hardy and will stand almost any degree of frost.

Salsify.—Lift and store.

Turnips.—Swedes stand frost well, in fact are best after they have been exposed for a little time to a low temperature. They may be left in the ground until needed, or lifted and stored in a pit.

Practical work.—Flowers.

Plant daffodils, hyacinths, spring crocuses, tulips, etc., as soon as the bed is clear of summer flowering plants. Plant in clumps, not singly. Let the bulb be covered with about 3 inches of soil. Crocuses should be 4 inches deep. See that tulips set in beds are at the same depth all over, or the flowers will not be at the same height later.

Dig over the ground where new plantations of herbaceous plants roses, etc., are to be set.

Insert in a cold frame cuttings of calceolarias, pansies, violas, pent, stemons, phloxes, etc.

Try sowing seeds of a few hardy annuals now (p. 155).

Practical work.—Fruit.

Root-prune fruit-trees (p. 245).

Prune currants (p. 253).

Take cuttings of black, white, and red currant, and of gooseberry bushes (p. 165).

NOVEMBER.

General remarks.—Digging should be finished during this month, as should all transplanting of fruit-trees and bushes as well as of perennial plants (p. 230). The herbaceous border should now be thinned out and reconstructed (p. 149). Leaves should be gathered and placed in a heap to form leaf mould, while turf should also be cut and laid in piles. Experimental work indoors should now begin to receive more attention than outdoor work.

Practical work.—Vegetables, etc.

Broad beans.—Where the climate and soil are suitable a sowing may be made now for an early crop to harvest late in the following spring.

Cauliflowers.—If any remain they should be lifted and transplanted in a very well sheltered position until used.

Celery.—Earth up finally. Protect where necessary.

Lettuce.—Admit plenty of air to those in cold frames (p. 160).

Onions.—Examine stored bulbs and remove those showing any signs of decay.

Practical work.—Flowers.

Plant border flowers, roses, bulbs, etc., after the ground which was dug in October has become well sunk. In the case of roses, well rotted farmyard or pig manure should have been worked into the lower layers of the soil, and the upper layer treated with some coarsely crushed bones together with half a pound of basic slag to the square yard. The junction of the stock and scion should be ½ to 1 inch underground in actual planting, and the roots well spread out.

Practical work.—Fruit.

Finish pruning small fruits (p. 253).

Spray apple trees as soon as the leaves have fallen.

Plant all fresh fruit-trees and bushes which are to be introduced (p. 230).

DECEMBER.

General remarks.—Work must be mostly done indoors, experiments being performed, garden requisites made, etc. Outdoor work will be restricted to making up for any omissions in the work of the previous month. Practically the same remarks hold good with regard to this month as are made in the case of January.

Practical work.—Vegetables, etc.

Potatoes.—Those stored should be examined and decayed tubers removed. Choose those required for "seed."

Practical work.—Flowers.

Take cuttings of chrysanthemums. This may be continued right on to March (p. 167).

Practical work.—Fruit.

Spray with caustic alkali wash all trees, etc., which show signs of any attack.

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